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Tech Notes

May 1989

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U.S. DEPARTMENT OF COMMERCE
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Tech Notes

Highlighting Selected U.S. Government Technology & Resources

May 1989

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Published monthly by the National Technical Information Service (NTIS), Tech Notes bring together individual one- to two-page fact sheets prepared by Federal agencies, their laboratories, or contractors. These fact sheets highlight current Federal technology determined to have commercial or practical application. Topics cover new processes, materials, techniques, software, instrumentation, and resources.

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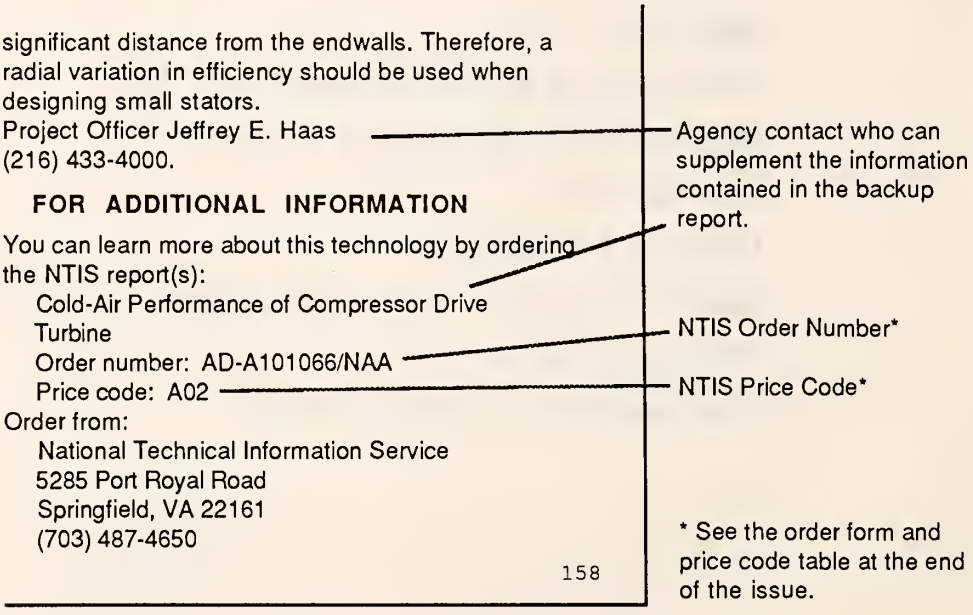
significant distance from the endwalls. Therefore, a radial variation in efficiency should be used when designing small stators.
Project Officer Jeffrey E. Haas
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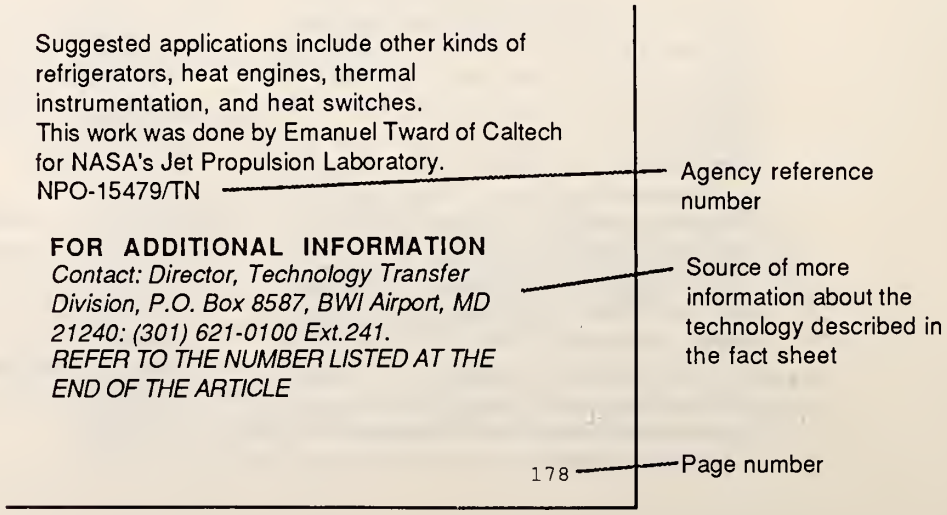
Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
NPO-15479/TN
FOR ADDITIONAL INFORMATION
Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE
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Source of more information about the technology described in the fact sheet
Page number

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0424 Airplane Takeoff-and-Landing Performance Monitoring System—An algorithm and display system are designed to increase the safety of flight. (Licensing Opportunity)

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Agriculture & Food

0336 New Matmaker Hastens Hay Making

0337 New Virus Mix Kills Insects in Raisins (Licensing Opportunity)

Testing & Instrumentation

0338 Solar-Powered, Infrared Bee Transmitter (Licensing Opportunity)

United States
Department of
Agriculture

Research Technology
Agricultural Research Service

New Matmaker Hastens Hay Making

A new machine could save farmers time and increase the value of their hay by letting them mow it in the morning and dry and bale it in the afternoon instead of days later, reports a scientist at the Agricultural Research Service.

A working prototype called the forage mat machine mows and immediately shreds alfalfa, says agricultural engineer Richard G. Koegel of ARS' U.S. Dairy Forage Research Center in Madison, Wisconsin.

"The machine then presses the shredded leaves and stems into a continuous, quarter-inch-thick mat and lays it on the stubble to sun-dry in 6 hours or less," he says. "The hay can be baled the same day if it sun-dries to the 20 percent moisture content required for baling."

That means less chance of rain damage to the crop. Also, hay processed by the new machine and fed to sheep was about 15 percent higher in fiber digestibility than hay cut and dried conventionally.

Using conventional equipment, called a mower-conditioner, a farmer normally waits 2 to 4 days for alfalfa to sun-dry to 20 percent moisture. A mower-conditioner crimps the stems, opening cracks that help them dry, but the leaves tend to dry faster—and may shatter from the stems and be lost during baling.

In contrast, the forage mat machine by shredding the plant exposes a lot of moisture, and this juice acts as adhesive to bind a homogeneous mix of leaves and stems into a mat that dries quickly and uniformly.

BRUCE FRITZ

Richard G. Koegel displays a section of matted alfalfa that was mowed, shredded, and pressed into a continuous mat by his prototype harvester in background.

"Gently placing the mats on the stubble without broken spots is the most challenging aspect of our work. And keeping a thickness of no more than one-quarter inch is critical to keeping drying time down," Koegel says.

After sun-drying, the hay is ready for harvesting by conventional methods, if desired. Round baling seems the easiest choice. For square baling, he thinks a baler that could fold the material like an accordion would be best. For silage, some way to pick up the hay and break up the mat structure before the hay is blown into the silo is needed.

An equipment manufacturer has started commercially developing the new machine. Koegel says they plan to refine the process so it will work with grasses as well as alfalfa.–

Richard G. Koegel is at the U.S. Dairy Forage Research Center, 1925 Linden Drive West, University of Wisconsin, Madison, WI 53706 (608) 263-5636. ♦

Research Technology
Argicultural Research Service
U.S. Department of Agriculture

Licensing Opportunity

New Virus Mix Kills Insects in Raisins

A powerful natural virus that kills raisin-eating moths may someday be applied to that food as an almost invisible tasteless and odorless protective powder or spray mist.

It would take only one-quarter teaspoon of the granulosis virus mixture to protect 450 one-pound boxes of raisins from the Indianmeal moth, says ARS research entomologist Patrick V. Vail at the Horticultural Crops Research Laboratory, Fresno, California.

Yet that protection won't alter the taste, texture, or appearance of the raisins. And safety tests, required before the virus mix could be approved for use on raisins or other stored foods that the moth eats, are expected to show that the virus is harmless to humans.

Indianmeal moth ranks as one of the top three pests of stored raisins, which is why the California Raisin Advisory Board funded part of the research. The insect is also a major headache for packers or processors of other dried fruits, including apricots and prunes, nuts such as almonds and walnuts, and grains like wheat and barley.

The adult moth is small and silvery, with narrow, blunt-tipped wings. It's the one that may "fly out at you when you open the kitchen cupboard," Vail says.

The process he developed for producing large quantities of the virus is less expensive and more effective than other ways researchers have suggested for putting the virus to work in warehouses and packing plants where the moth is a continuing problem.

To produce the virus mix, the insects are reared from eggs in the laboratory. Their meals are a combination of wheat bran, yeast, and vitamins. Honey and glycerol, two ingredients other researchers had suggested were critical sources of vitamins, minerals, and sugar for the insects, are left out because they're sticky. They had to be washed off in later steps, driving up costs.

The larvae (wormlike stage) that hatch from the eggs are incubated for 10 days at 80°F until they are about half-grown. Then their food is spiked with ground-up remains of a small number of laboratory-reared larvae that had been exposed to the virus. After a second incubation stint of another 10 days at 80°, about 90 percent of the larvae will come down with the virus.

By this time, the viruses in their bodies will have increased millions of times. "They have essentially served as little factories for quickly producing a huge amount of virus," Vail says.

That's when larvae and food, along with some water, go into the blender. The resulting slurry, loaded with active virus, is freeze-dried, then milled to a fine, buff-colored powder, about the consistency of bleached flour. The powder could be used right away or could be stored in a refrigerator or freezer.

The virus mix could be added to water, then sprayed on the food. Or it could be blended with a carrier, such as milled wheat bran, then lightly dusted on raisins. Another option could be to use the virus mix in combination with an insect attractant to lure adult moths to a trap where they'd be exposed to the virus.

Vail says the virus mix is a natural biological control that with further development might give food processors an alternative to chemical fumigants.

FOR ADDITIONAL INFORMATION: For technical information about this patent, contact Patrick V. Vail, USDA-ARS Horticultural Crops Research Laboratory, 2021 South Peach Ave., Fresno, CA 93927; (209) 453-3000.

Department of Energy

Licensing Opportunity

Technology Application

Oak Ridge National Laboratories

Solar-Powered, Infrared Bee Transmitter

Engineers at ORNL have developed the prototype of a silicon chip that will be used to monitor Africanized honeybees. This transmitter, a very-large-scale integrated circuit, contains two infrared laser diodes powered by an on-board array of microminiature solar cells. The 3 × 5 mm chip, which weighs about 35 mg, can be glued to the thorax of a honeybee (Fig. 1). As the tagged bee flies, signals from the transmitter can be tracked by ground-based receivers at distances of up to 1 mile.

Hundreds of thousands of so-called "killer bees" have been migrating northward from Brazil ever since African queen bees (*Apis mellifera scutellata*) escaped from a laboratory there in 1957. The "Africanized" descendents of these queens, created through matings with the more docile European bees (*Apis mellifera mellifera*), have nearly destroyed commercial beekeeping operations throughout the territories they have occupied.

Africanized bees are expected to enter Texas from Mexico by 1989. Their arrival will threaten the production of crops that depend on honeybees for pollination ($20 billion annually). Africanized bees pose a further threat because they are known to have fatally stung both animals and people. The infrared transmitter will help Department of Agriculture officials study the mating and foraging habits of the Africanized bees. These data will be used in an attempt to control the migration without using large quantities of pesticides.

Fig. 1. An ORNL engineer attaches a prototype of a solar-powered, infrared transmitter to the thorax of a European honeybee drone.

The transmitter can be attached to the bee using either an organic glue or ordinary nail polish. Neither substance is harmful to the insect, and both have been used frequently in the past by beekeepers who mark their queens with

colored, numbered tags. The bee's flight should not be hindered by the lightweight transmitter; previous tests by the USDA have shown that worker bees are capable of carrying up to 47 mg with no flight impediment.

Because of its very small size and weight, and because the solar cells can be replaced with batteries, this transmitter has many other applications:

- for other biological field work, such as tracking and studying butterflies or hummingbirds;
- as a biomedical monitor, for monitoring the movement of severe burn patients or patients in traction;
- for security applications, as an alarm system used to prevent the removal of sensitive material to which it is attached; and
- in the transportation industry, to monitor the shifting of cargo in holds of ships, airplanes, or trucks.

Additional information:

Office of Technology Applications
Martin Marietta Energy Systems, Inc.
P.O. Box 2008
Oak Ridge, TN 37831-6257

Telephone: (615) 574-4192; FTS 624-4192

Further documentation of this technology is being prepared.

Computers

0339 Additive Single and Multilayer Hybrid Circuitry

0340 Biodirectional Single-Mode Fiber Optic System is Possible without Optical Repeaters

0341 OPSNET: Parallel Architecture for Expert Systems

0342 Publishing Standard Allows for the Transfer of Documents from Author to Publisher

0343 Radar-Data-Processing System—A fast, complex, versatile system features reliable equipment and computer programs. (Licensing Opportunity)

Other Items of Interest

0373 Nondestructive Testing with Pulsed Eddy Currents

U.S. Army Fact Sheet

U.S. Army Industrial Engineering Activity, Rock Island, IL 61299-7260

Additive Single and Multilayer Hybrid Circuitry

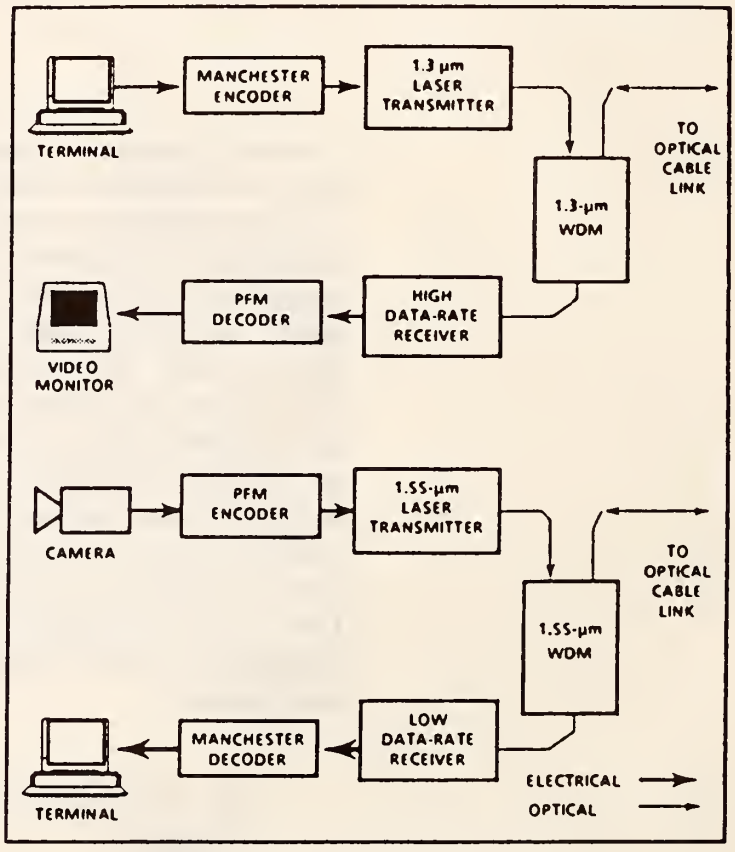
General Dynamics developed a process utilizing semi-additive techniques to fabricate 10-layer multilayer boards with 2-mil lines and spaces. The process demonstrated the ability to fabricate 1-mil lines and spaces, fabricated special high precision chrome photo tools and developed a non-destructive registration verification system. In conjunction with process development, an extensive materials and machinability evaluation was conducted to select board materials having a finish and physical properties suited to the project requirements. Use of this semi-additive process made it possible to populate boards up to 92 percent density.

For Additional Information:
J. Sergant
AMXIB-PA
U.S. Army Industral Engineering Activity
Rock Island, IL 61299-7260
(309) 782-5617

Biodirectional Single-Mode Fiber Optic System is Possible without Optical Repeaters

Investigators at Navy Ocean Systems Center, San Diego, California, have learned that full-duplex, bidirectional command control, and television data can be successfully transmitted through 100 kilometers (km) of optical fiber without using optical repeaters.

Commercially available off-the-shelf components were used throughout the system. Optical sources were injection laser diode transmitters operating wavelengths of 1.3 and 1.56 micrometers (μm). Optical detectors were InGaAs (indio gallium arsenide) photodiodes coupled to GaAs FET transimpedance amplifiers. Data were transmitted by single-mode, dispersion-shifted optical fiber, while television imagery was transmitted using pulse-frequency modulation. Bulk optic wavelength-division multiplexers isolated the two optical data paths from each other, and a Manchester decoder-encoder processed data. The total link length was estimated to be 110 km, and projected length after improvements is estimated to be 200 km.



A 100-km, bidirectional single-mode fiber optic system.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 131104/TN

Oak Ridge National Laboratories

OPSNET: Parallel Architecture for Expert Systems

OPSNET, a new parallel computer architecture developed at ORNL, captures some of the parallelism inherent in expert systems programs and makes impressive performance gains over conventional architectures. A central feature of this architecture is a network bus over which a host processor broadcasts messages to a set of parallel rule processors. This architecture can be implemented with any number of parallel processors (Fig. 1). An existing prototype computer system uses a host and 64 parallel rule processors (Fig. 2) and, in a smaller package, a host and 8 rule processors.

Expert system programs consist of many "if-then" rules, each of which must be evaluated repeatedly according to available data. For complex systems containing thousands of rules and for systems that must keep up with a real-time process, the performance of expert systems on conventional computer architectures can be disappointing. The new OPSNET architecture divides the work of matching rules with data among rule processors, each of which works independently on its part of the problem.

OPSNET was developed especially for OPS5, one of the oldest and best established expert systems languages. An important feature of the prototype systems is that they execute standard OPS5 code directly. The programmer makes no explicit references to the parallelism in the program; the software and hardware are designed to transparently take advantage of the inherent parallelism.

This technology opens up new applications for expert systems and speeds up old ones. For

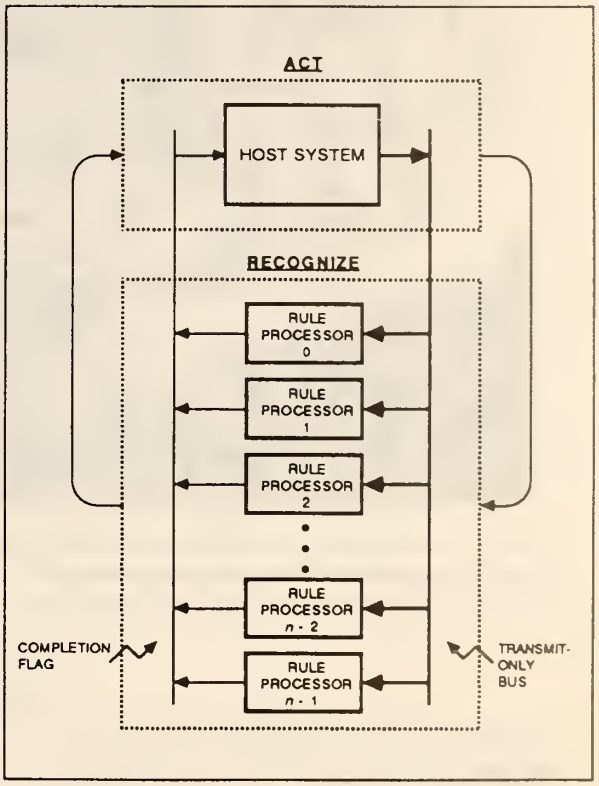


Fig. 1. Diagram of the OPSNET architecture. The host system can support any number (*n*) of parallel rule processors.

Fig. 2. ORNL researchers examine one of the 16 parallel rule processor boards included in this OPSNET prototype. Each board contains four processors.

example, it has been applied to solving the problems of chemical synthesis and waste management. It has also been proposed for applications in complex process control, intelligent robotics, image processing, and cognitive science.

Additional information:

Office of Technology Applications
Martin Marietta Energy Systems, Inc.
P.O. Box 2008
Oak Ridge, TN 37831-6257

Telephone: (615) 574-4192; FTS 624-4192

P. L. Butler et al., "Parallel Architecture for OPS5," pp. 452-57 in *15th Annual International Symposium on Computer Architecture, Honolulu, Hawaii, May 30-June 2, 1988*, Institute of Electrical and Electronics Engineers, Inc., Washington, D.C., 1988.

P. L. Butler, J. D. Allen, Jr., and D. W. Bouldin, "Design and Implementation of a Parallel Computer for Expert System Applications," pp. 638-45 in *Applications of Artificial Intelligence VI*, ed. Mohan M. Trivedi, SPIE—The International Society for Optical Engineering, Bellingham, Washington, 1988 (*Proceedings of SPIE—The International Society for Optical Engineering*, Vol. 937).

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Publishing Standard Allows for the Transfer of Documents from Author to Publisher

A Federal Information Processing Standard (FIPS) recently approved by the Secretary of Commerce should help federal agencies improve their communications with publishing organizations. (FIPS are developed by NIST for use by the federal government.) The new standard, called Standard Generalized Markup Language (SGML), provides a common way for defining markup languages so documents can be transferred from author to publisher in a standardized format. By providing a coherent and unambiguous syntax for describing the elements within a document, SGML makes it easier to move unformatted textual data among different installations and processing systems. Developed by the International Organization for Standardization (ISO) and the American National Standards Institute(ANSI) with assistance from NIST, the SGML standard is already being used by the Computer-Aided Acquistion and Logistics Support (CALS) program of the Department of Defense to develop a military specification. NIST is providing technical support for the CALS program. In addition, NIST has developed the first set of conformance tests for SGML; ISO and ANSI are considering using these tests for their own test suites.

FOR ADDITIONAL INFORMATION:FIPS 152, Standard Generalized Markup Language (SGML).

NTIS order number: FIPS PUB-152/NAL
Price Code: E19

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Radar-Data-Processing System

A fast, complex, versatile system features reliable equipment and computer programs.

A report describes the radar data system at the NASA Western Aeronautical Test Range. This system provides real-time and recorded data about the flightpaths of research aircraft and the Space Shuttle. The system, called RADATS, processes data from three radars simultaneously; interacts with the system operator; enhances the data by introducing corrections and smoothing; controls the range, azimuth, and elevation of the radars; and automatically calibrates itself before and after missions.

The RADATS computer is based on a distributed-intelligence concept in which the input/output instructions are processed separately from other types of program instructions. The central processing unit (CPU) is linked to input/output processors on each interface channel. The CPU carries out 3 million instructions per second and processes 500,000 floating-point operations per second. It contains 768 kilobytes of error-correcting-code memory, expandable to 6 megabytes.

Built-in programs in the input/output processors autonomously control all input/output operations, including chained, multiple, direct-memory-access transfers of incoming and outgoing streams of data. The processors accomplish the transfers without interrupting the CPU except at the beginning and end of each input/output task and when new buffers with updated data are linked into a chain. The input/output processors transfer input and output data at rates up to 3.7 and 3 megabytes per second, respectively. Measurement input data and formatted output data are given priority in transfers because they run on fast cycles and must occur precisely on time.

The RADATS software is classified into three kinds of programs: utility, real-time, and calibration. The utility software includes programs to enter channel and frame formats, to reduce or compare data, and to perform geodetic computations and other computations associated with surveying and with the installation and calibration of equipment. The real-time software includes programs for such functions as the formatting and decoding of data, calculations of ranges and angles, digital filtering, calculations of state vectors, capture of real-time data for recording, and playback of recorded data. The calibration software includes programs that assure the accuracies of optical and radio-frequency tracking equipment.

At the operator console, the RADATS provides virtually all the information the operator needs for control before, during, and after a mission. It also gives the operator real-time answers about the effects of adjustments.

The equipment has exhibited exceptional reliability; the system has never failed to perform during mission support. The software has matured to become virtually trouble-free.

This work was done by Karl F. Anderson and John W. Wrin of **Ames Research Center** *and Robert James of GMD Systems. Further information may be found in NASA TM-88274 [N86-29884/NSP], [price code: A02] "A Radar Data Processing and Enhancement System."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center. Refer to ARC-11782/TN.

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Electrotechnology

0344 Conversion Losses in GaAs Schottky-Barrier Diodes—Parasitic losses can be reduced with lightly doped epitaxial layers of proper thickness.

0345 Detector Arrays for Infrared Astronomy—The status of a development program is reviewed. (Licensing Opportunity)

0346 Frequency-Accommodating Manchester Decoder—No adjustment is necessary to cover a 10:1 frequency range.

0347 Empirical Modeling of Single-Event Upset—Experimental data support a worst-case model.

0348 Linear-Quadratic Controller for Aiming a Large Antenna—Independent control and estimator gains are selected for optimal performance.

0349 Noise Performance of a Digital Tanlock Loop—A slight improvement over a sinusoidal phase-lock loop can be achieved.

0350 Nonuniform Sampling of Radiation from Antennas—Far-field patterns can be reconstructed.

0351 Response of a MOSFET to a Cosmic Ray—Susceptibility to single-event upset is analyzed.

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0353 Stacked Metal Silicide/Silicon Far-Infrared Detectors—The long-wavelength limit would be extended. (Licensing Opportunity)

Testing & Instrumentation

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Other Items of Interest

0338 Solar-Powered, Infrared Bee Transmitter (Licensing Opportunity)

0340 Biodirectional Single-Mode Fiber Optic System is Possible without Optical Repeaters

0360 Photovoltaic Concentrator Cell Achieves Record Efficiency

NASA Tech Brief
National Aeronautics and Space Administration

Conversion Losses in GaAs Schottky-Barrier Diodes

Parasitic losses can be reduced with lightly doped epitaxial layers of proper thickness.

A report presents calculations of conversion losses in Schottky-barrier diodes. This theoretical work is directed toward the reduction of parasitic losses through the proper design of space-charge layers: it is possible, by such efforts, to reduce barrier capacitances and contributions to barrier resistances from undepleted epitaxial layers.

The parasitic loss, L, of a device is defined as the ratio of the total power absorbed to the power available to the barrier resistance alone. The authors present a cylindrical diode model and equivalent circuit for which

$$L = 1 + R_s/R_b + \omega^2 C^2 R_s R_b$$

where R_s = the spreading resistance, R_b = the barrier resistance, C = the barrier capacitance, and ω = the angular frequency. Consequently, L can be minimized by making R_s and C as small as possible.

R_s is calculated by applying a previously developed theory of the impedance to a current flowing through a small circular disk into a substrate consisting of a homogeneously doped semiconductor. Because terms that were neglected in approximations by previous researchers are included here, the result is more accurate. For example, in a GaAs diode having representative dimensions and semiconductor-material parameters, the previous approximate value is found to be 30 percent too high.

The barrier capacitance is given by

$$C = \varepsilon_o \varepsilon_r \pi a^2 / W$$

where ε_o is the electric permittivity of free space, ε_r is the relative dielectric constant, a is the radius of the Schottky contact, and W is the width of the depletion layer. Since C must be kept small to minimize losses, W must be made large. This can be done by decreasing the dopant concentration, but then the contribution of the undepleted epitaxial layer to R_s increases because the light doping reduces the conductivity.

However, the epitaxial-layer ac resistance can be avoided if the alternating currents can be made to be supported entirely by displacement currents in the space-charge region, by extending the space-charge layer into the substrate. Thus, C and R_s can be reduced simultaneously and losses therefore made smaller by space-charge "punch-through."

The theoretical conversion loss is calculated for the representative GaAs diode (which achieves "punch-through") and plotted as a function of frequency, up to about 10 THz. Also plotted is the conversion loss for a more-heavily-doped conventional model that does not achieve "punch-through." The conversion loss of the conventional diode is higher by about 22 dB at a frequency of 10 THz.

This work was done by Oldwig von Roos and Ke-Li Wang of Caltech for **NASA's Jet Propulsion Laboratory**.

"Conversion Losses in GaAs Schottky-Barrier Diodes," NPO-16700/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Detector Arrays for Infrared Astronomy

The status of a development program is reviewed.

A paper describes the status of a program for developing integrated infrared detectors for astronomy. The program covers a variety of detectors, including extrinsic silicon, extrinsic germanium, and indium antimonide devices with hybrid silicon multiplexers:

- A 32- by 32-element indium antimonide charge-coupled device has been evaluated in the laboratory and incorporated in an astronomical instrument for observations from the ground. The testing equipment and software for this device are being modified for a 58-by-62-element direct-readout (DRO) InSb array.
- Two-dimensional accumulation-mode Si:Bi charge-injection device arrays in 16-by-16 and 2-by-64 formats have been tested and used in astronomical applications.
- DRO Si:As arrays in a 10-by-64 format have been used in field tests, and astronomical images have been obtained from them.
- Two-dimensional back-illuminated Si:As blocked-impurity-band (BIB) arrays in a 10-by 50-element format are being designed and built. They will include switched field-effect transistor (FET) multiplexers modified to provide nondestructive readout of charge. Tests of dark current of a 10-element front-illuminated Si:As BIB array are underway.
- An investigation of the applicability of discrete Si:As solid-state photomultipliers will explore analytically and experimentally the nature of dark counts (which would limit sensitivity in a cooled telescope).
- To extend the spectral coverage of extrinsic silicon integrated arrays to 30 μm, arrays with Si:Sb detector material have been combined with a silicon DRO multiplexer.
- Ge:Ga detectors in 1-by-8 modules with switched FET readouts have been developed to explore the feasibility of adapting the technology of low-noise integrated arrays to long-wavelength extrinsic germanium detectors.

The paper notes that for arrays to reach the background noise limit in a cryogenic telescope, continued reductions in readout noise and dark current will be needed. The effects of impacts of energetic charged particles should be understood better so that the properties and operating points of devices can be optimized. Better understanding of the imaging properties and image-processing requirements of arrays is also needed.

This work was done by C. R. McCreight, M. E. McKelvey, J. H. Goebel, G. M. Anderson, and J. H. Lee of **Ames Research Center**. *Further information may be found in NASA TM-88344 [N87-24378/NSP], [price code: A02] "Detector Arrays for Low-Background Space Infrared Astronomy."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Frequency-Accommodating Manchester Decoder

No adjustment is necessary to cover a 10:1 frequency range.

A decoding circuit converts biphase-level pulse-code modulation to nonreturn-to-zero (NRZ)-level pulse-code modulation plus a clock signal. The circuit accommodates an input data rate of 50 to 500 kb/s. It tracks gradual changes in the rate automatically, eliminating the need for extra circuits and manual switching to adjust to different rates.

The circuit (see Figure 1) is based on the 3/4-data-cell one-shot decoder, which synchronizes itself to biphase data and yields NRZ data and a 75-percent-duty-cycle clock. It may initially synchronize with phase-change transitions and produce incorrect output, but resynchronizes itself to clock transitions at the first 0-to-1 or 1-to-0 data pattern, thereafter giving a correct output. The new decoder is a 3/4-cell one-shot that continuously adjusts its period to remain at 75 percent of the input data-cell period over a range of input rates.

The input signal triggers Z_1, a bidirectional one-shot. The Z_1 timing components are selected to produce a timing period longer than the longest data cell (from the lowest frequency) to be decoded. The Q output of Z_1 goes high, starting a ramp generator consisting of Z_2, Q_1, R_2, and C_2. As time passes, the output of the ramp generator rises and is monitored by the positive input of comparator Z_3. When the ramp reaches reference voltage V_{ref} at the negative input of Z_3, the output of Z_3 goes high, clearing and prematurely terminating the output pulse of Z_1. This, in turn, resets the ramp generator to 0 V. Z_1 then remains idle until the next input data transition (Figure 2).

Voltage V_{ref} is generated as follows: Z_4 is connected in feedback to toggle with each output pulse of Z_1. The output of Z_4 oper-

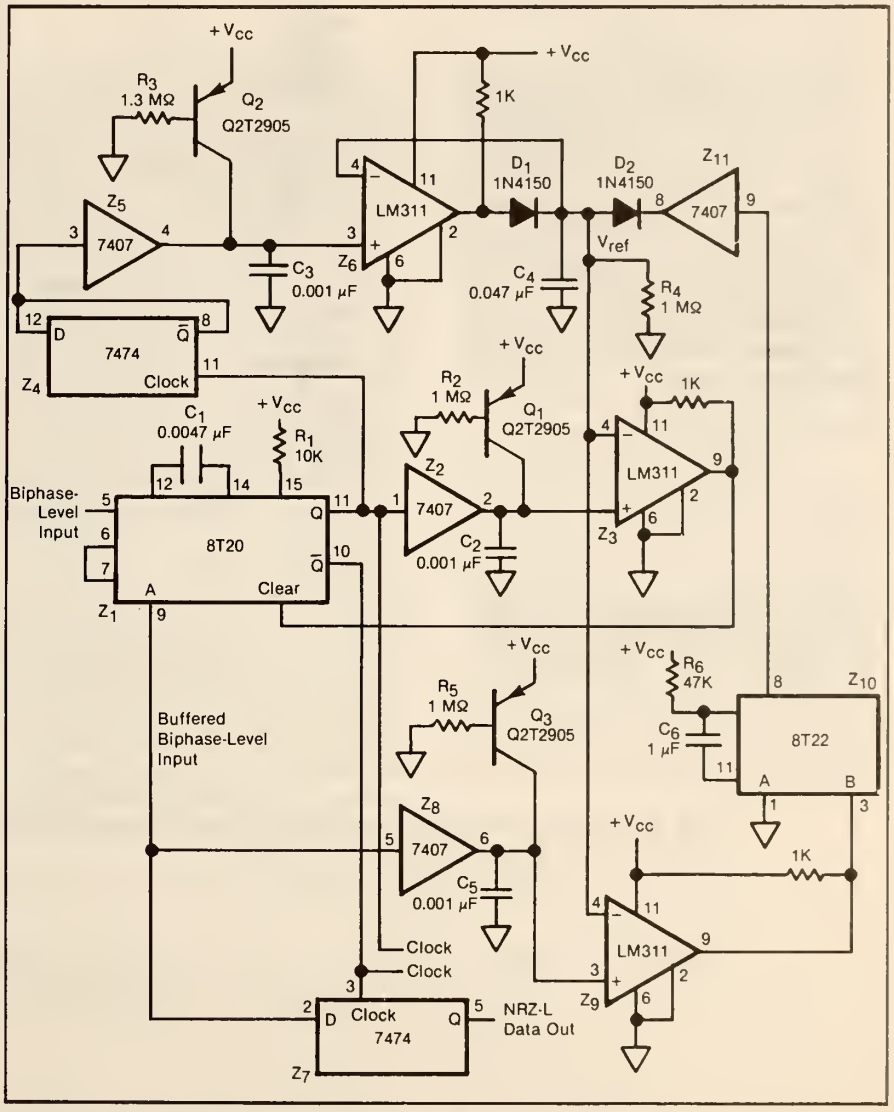

Figure 1. The **Frequency-Accommodating Manchester Decoder** converts biphase-level input to NDZ-L output at any input data rate from 50 to 500 kb/s. The decoder is based on the ¾-data-cell one-shot circuit.

ates a second ramp generator (Z_5, Q_2, R_3, and C_3). This produces a waveform with a peak amplitude directly proportional to the period of the data cell. This waveform is peak-detected by Z_6, D_1, C_4, and R_4, producing V_{ref}, a dc level representing the period of the data cell.

The data-cell ramp (at C_3) is designed to give a peak near V_{cc} for the longest data cell to be handled. The ¾-cell ramp generator (at C_2) is designed with a time constant of three-quarters that of the data-cell ramp generator. Therefore Z_1 is cleared at 75 percent of the data-cell period.

Once synchronized with the input, V_{ref} is generated to represent the incoming data rate. V_{ref} and the ¾-cell ramp produce a ¾-cell one-shot function of Z_1. The biphase input is connected to the D input of Z_7 through the A output of Z_1. Z_7 is clocked with the inverted output of Z_1 to yield the NRZ-L data. The output of Z_1 may be used as a clock for the NRZ-L data.

This work was done by Mario J. Vasquez of Rockwell International Corp. for **Johnson Space Center**.

MSC-21312/TN

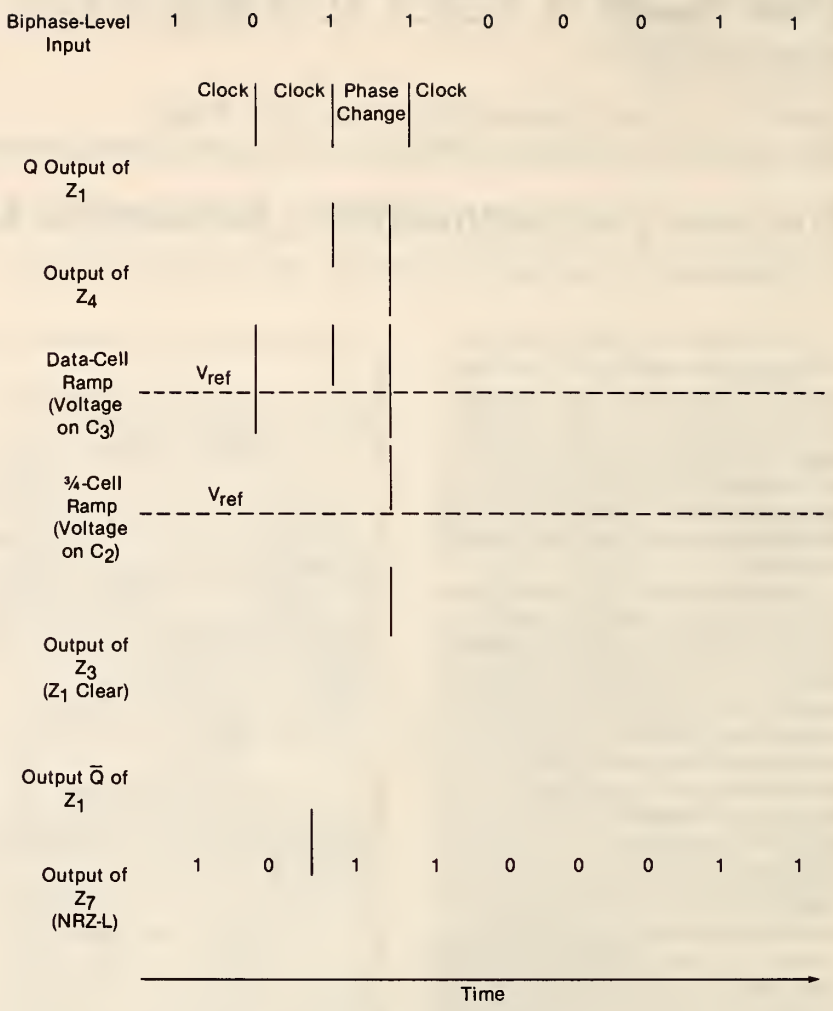

Figure 2. These **Waveforms Are Produced by the Decoder** when it is operating in synchronism with the biphase-level input signal.

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NASA Tech Brief
National Aeronautics and Space Administration

Empirical Modeling of Single-Event Upset

Experimental data support a worst-case model.

An experimental study presents examples of the empirical modeling of single-event upset (SEU) in negatively-doped-source/drain metal-oxide-semiconductor (NMOS) static random-access memory (SRAM) cells. Viewed as a whole, the experimental data support the adoption of a simplified worst-case model in which the cross section for SEU by an ion above a threshold energy equals the area of the memory cell.

The study included three design iterations of a depletion-made-load, high-performance NMOS SRAM, with electrical-channel lengths of 2.5, 1.6, and 1.1 μm and gate-oxide thicknesses of 700, 400, and 250 Å, respectively. The depletion-mode, pullup-load devices were n-channel transistors maintained in the conducting state by connecting their source and gate nodes with polysilicon lines that were also connected to the drain node of each n-channel, enhancement-mode pulldown device. The SRAM chips of each design iteration contained 4,096 bits with 1,024 × 4 (1,024 4-bit words) architecture. Each bit was embodied in a six-transistor cell.

The circuit chips were exposed to energetic bromine, iron, and carbon ions at the Brookhaven National Laboratory tandem van de Graaff accelerator. The number of SEU's produced by the ions and the ion energies were recorded. All of these SEU data are extremely accurate, enabling the correlation of the measured SEU cross sections with geometrical areas within each memory cell. To achieve the desired degree of accuracy, the number of errors (SEU's) counted plus the ion energy selected for each data point are such that the experimental uncertainty (error bars) falls within the data points as drawn on plots of the SEU cross section as a function of the ion energy.

In a memory cell of the type tested, a penetrating ion of stopping power greater than 35 MeV-cm^2/mg can cause SEU by striking virtually any region of the cell. This is manifested by the experimental data in which the SEU cross section per bit approaches the total area of the cell at such stopping powers. An NMOS memory cell has only one sensitive node. Therefore, SEU is apparently caused by charge collection at that sensitive node via diffusion from a high-stopping-power ion track anywhere in the cell.

For ions with energies near and above the threshold for SEU, upsets occur when the ion tracks intersect the charge-collecting junction connected to the sensitive node. For these lower-stopping-power events, the ionized charge is collected primarily by electric-field-aided drift, and the experimental values of the SEU cross section per bit can be correlated with geometrical features (i.e., areas of charge-collecting junctions) within a cell.

This work was done by John A. Zoutendyk, Lawrence S. Smith, George A. Soli, of Caltech; Peter Thieberger of Brookhaven National Laboratory; and Stephen L. Smith and Gregory E. Atwood of Intel Corp. for **NASA's Jet Propulsion Laboratory**. *"SEU Modeling Verification of NMOS Depletion-Mode-Loan SRAMS" and "Empirical Modeling of Single-Event Upset (SEU) in NMOS Depletion-Mode-Load Static RAM (SRAM) Chips," NPO-16920/TN*

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NASA Tech Brief
National Aeronautics and Space Administration

Linear-Quadratic Controller for Aiming a Large Antenna

Independent control and estimator gains are selected for optimal performance.

A report describes the use of the techniques of linear-quadratic optimal control to design a digital controller that would aim a large antenna. The controller would be based on a closed-loop concept that includes a mathematical model of the plant (that is, the antenna and the associated aiming motors, gears, and related equipment) and an independently-selectable mathematical model that estimates the state of the system.

The report begins by reviewing the theory of linear-quadratic optimal control, in which one seeks to minimize a quadratic performance index that penalizes the transient deviation of the state from the desired state and the control effort expended in fighting the deviation. In this application, the controller uses state feedback so that it can specify arbitrarily the eigenvalues of the closed position-control loop.

The control system is represented as a set of first-order differential state equations, and each state is multiplied by a gain. The summed results are used as a commanded rate for the rate-control loop.

Because it is impossible or too expensive to measure many states, the system includes a dynamic estimator, which estimates the value of each state based on measurable states and a mathematical model of the plant. The dynamics of the closed-loop system depend on the combined eigenvalues of the controller and the estimator. However, the design of the controller is independent of the design of the estimator because the gains of the estimator do not alter the dynamics of the controller and the gains of the controller do not alter the dynamics of the estimator.

A simplified transfer-function model of the rate-control loop of the plant was developed and verified by fitting curves to measurements of gain and phase as functions of frequency-response data. The model was mapped into a diagonal canonical set of state equations, which were augmented to include position and integral-of-position states. Weighting matrices were selected, and families of optimal gains were calculated on the basis of the augmented model. The closed-loop system was simulated with each gain vector, and the "best" gain was selected according to the performance index and the performance specifications.

The integral-of-position state was eliminated, and the third-order model was used to design a new state estimator. Estimator dynamics were selected and estimator-gain vectors calculated. The selected control-gain vector was simulated with each estimator-gain vector using a high-order model of the plant with mismatch of the model, structural resonances, and effects of quantization in the analog-to-digital angle encoder. An estimator-gain vector was selected to minimize the effects of quantization and the estimator error.

This work was done by Jackson A. Nickerson of Caltech for **NASA's Jet Propulsion Laboratory**.

"A New Linear Quadratic Optimal Controller for the 34-Meter High Efficiency Antenna Position Loop,"

NPO-17388/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Noise Performance of a Digital Tanlock Loop

A slight improvement over a sinusoidal phase-lock loop can be achieved.

A report discusses theoretical studies and numerical simulations of the performance of a digital tangent phase-lock loop (DTL) in the presence of noise. The performance is measured in terms of the phase-error variance and the mean time to skip cycle, both as a function of the input signal-to-noise ratio (SNR). For purposes of comparison, similar studies were conducted for a sinusoidal digital phase-lock loop like those in common use.

The analysis assumes a received signal $r(t)$ of the form

$$r(t) = A \sin [\omega_o t + \theta(t)] + n(t)$$

where A is amplitude, t is time, ω_o is the carrier angular frequency, θ is the signal phase, and n is the narrow-band Gaussian noise. The in-phase and quadrature components are sampled, yielding two sinusoidal components, $x(k)$ and $y(k)$ (for the kth sample), given by

$$x(k) = A \sin \phi(k) + n'(k) \text{ and}$$

$$y(k) = A \cos \phi(k) + n'(k)$$

where $\phi(k)$ is the phase error of the kth sample and n' is an independent Gaussian noise in the quadrature channel. The output $e(k)$ of the phase detector for the kth sample is then expressed as

$$e(k) = x(k)/y(k)$$

which would equal the tangent of the phase error in the absence of the noise.

The probability distribution function for $e(k)$ has been derived and is used to calculate the S-shaped curves that show the expectation (average) value of the phase-detector output as a function of the phase error for various signal-to-noise ratios. The noise in the tanlock phase-detector output has characteristics that depend heavily on the phase error and that are different from those of a sinusoidal phase detector. As a consequence, the S-curve analysis of the DTL is not as useful as it is in the sinusoidal case.

Numerical simulations of performance were carried out under various assumptions regarding the stochastic processes and filter equations involved. The mean times to skip cycle were found by calculating the mean numbers of cycles required to go from a phase error of zero to an error of $\pm 2\pi$.

Overall, the authors found that at an SNR of 5 or more, there is practically no difference in phase-error variance between the DTL and the sinusoidal loop, while at low to moderate SNR, the DTL exhibits a slightly smaller variance. At high SNR, the mean time to skip cycle of the DTL is less than that of the sinusoidal loop: this is a disadvantage. However, at low SNR, the difference in mean times to skip cycle is not significant. In consideration of the foregoing plus the extended linear range of the DTL, it appears to be somewhat advantageous to use the DTL where the input SNR is low to moderate.

This work was done by W. J. Hurd and C. A. Pomalaza-Raez of Caltech for **NASA's Jet Propulsion Laboratory**.

"Noise Performance of a Digital Tanlock Loop," NPO-16960/TN

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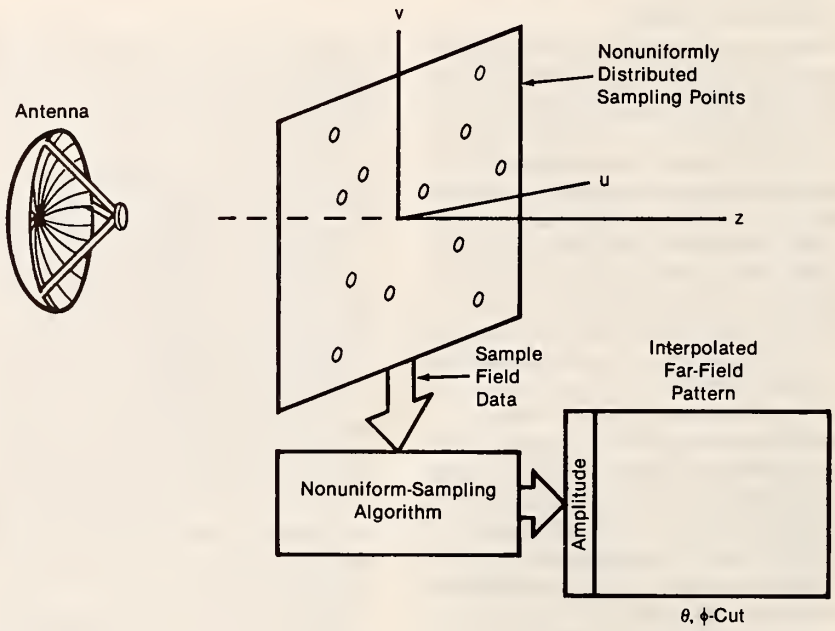
NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Nonuniform Sampling of Radiation From Antennas

Far-field patterns can be reconstructed.

A mathematical technique constructs the far electromagnetic field of a paraboloidal or other antenna at desired angular intervals by interpolation from measurements of the far fields (amplitude and phase) at sparsely and unevenly distributed locations (see figure). This is a two-dimensional sampling technique, the form of which depends only on the measurement locations and not on the measured field values. Nonuniform sampling could be particularly useful where the movements of the measured or measuring antenna cannot be controlled precisely. One recent example is the proposed measurement concept of large antennas aboard the Space Shuttle.

The technique is applicable to any components of the electric field **E** at measurement locations in a spherical coordinate system centered at the antenna. The electric field at these points is closely related to the radiation integral **T** based on the currents **J** induced on the surface of the antenna by the illuminating field.



The **Nonuniform-Sampling Technique** uses an interpolation algorithm to obtain the far-field radiation pattern of an antenna at any point *u*, v based on measurements at a few sampling points.

If one can assume that the component of **T** along the polar (*z*) axis is negligible (or, equivalently, that **T** is approximately a Fourier transform of a spatially limited function or that one can use an aperture-field model), then one can invert the matrix operator in the equation for **E** as a function of **T**. This amounts, in effect, to the calculation of **J** from the samples of **E**, followed by the use of **J** to calculate **E** at desired locations. However, one does not calculate **J** explicitly but, instead, uses either of two interpolation algorithms.

The algorithms use Cartesian measurement-point coordinates u, v, using $u = \sin\theta\cos\phi$ and $v = \sin\theta\sin\phi$, where θ is the polar angle and ϕ is the azimuthal angle in the spherical coordinate system. In the first algorithm, the electric field at any angle within the sampled domain can be reconstructed by

$$\mathbf{E}(u,v) = \sum_{i=1}^{N} \mathbf{E}(u_i, v_i)\,\psi_i(u,v)$$

where the subscripts denote particular samples, N = the number of sampling points, and the $\psi_i(u,v)$ are interpolation functions that only depend on the sampling locations. The second algorithm is adapted from uniform-sampling theory and is based on

$$\mathbf{E}(u,v) = \sum_{n,m} \mathbf{A}_{nm}\,F_{nm}(u,v)$$

where the F_{nm} are other interpolation functions and the $\mathbf{A}_{nm}$ are vectors that are obtained by matrix inversion and depend on both the field values and the sampling locations.

The sampling window can be shifted from the main beam to the side-lobe region. Numerical simulations show that the sampling technique can recover the side lobes at relatively wide observation angles, even without any knowledge of the main lobe. Moreover, one can reconstruct the far-field pattern over a wide angular range by combining the far fields obtained by sampling over narrower adjacent or overlapping ranges. Many measurements have been performed to demonstrate the accuracy of the technique.

This work was done by Y. Rahmat-Samii and R. L. Cheung of Caltech for **NASA's Jet Propulsion Laboratory.**

NPO-16961/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Response of a MOSFET to a Cosmic Ray

Susceptibility to single-event upset is analyzed.

A theoretical paper discusses the response of an enhancement-mode metal oxide/semiconductor field-effect transistor (MOSFET) to a cosmic-ray ion that passes perpendicularly through its gate-oxide layer. Even if the ion causes no permanent damage, the temporary increase of electrical conductivity along the track of the ion can be large enough and last long enough to cause a change in the logic state (a single-event upset) in a logic circuit that contains the MOSFET.

The gate of the MOSFET is modeled as a simple structure resembling a multilayer parallel-plate capacitor of capacitance C_{ox} with the aluminum gate as the positive electrode, the oxide layer as the insulator, and the n-channel and depletion layer as parts of a structured negative electrode. The effects of the external circuitry are summarized by a gate/source bias voltage V_{GS} applied through a Thévenin equivalent resistance R_T. The effect of the ion on the circuit is represented by a resistor R_C across the capacitor.

The increase in conductivity along the ion track is attributed to the creation of electron/hole pairs, the density of which is computed from a simple model involving the stopping power of the oxide with respect to ions of a given energy. The hole current and the diffusion currents of electrons and holes are assumed to be negligible: One of the consequences is that the duration of the ion track is governed by the recombination of holes and electrons. A typical recombination time is about 1 μs.

The analysis shows that R_C is inversely proportional to the stopping power and independent of the cross-sectional area of the ion track. Assuming values of R_C and C_{ox} typical of those in real devices, the ion track discharges the gate capacitor from the bias voltage V_{GS} to a lower voltage $[R_C/(R_C+R_T)]V_{GS}$ within about 1 ns or less time. If this lower gate voltage is less than the threshold V_T, then the MOSFET turns off and remains off for the duration of the ion track.

If the affected MOSFET is one of a pair that forms a bistable circuit, then the other MOSFET (with a typical turn-on time of a few nanoseconds) turns on, thus completing the single-event upset. The vulnerability to single-event upset can be reduced by designing the circuit to prevent the gate voltage from going below V_T. One way is to increase V_{GS}, subject to limitation by the breakdown voltage of the gate oxide. Another way is to choose the resistances of the bias circuitry to reduce R_T.

This work was done by Reuben Benumof and John A. Zoutendyk of The College of Staten Island for **NASA's Jet Propulsion Laboratory**.

"Response of a MOSFET Circuit to a Cosmic-Ray Ion Track."
NPO-17146/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Selecting Wire Sizes for Switching Power Supplies

A computer program eliminates trial and error.

A computer program determines the size and number of strands of wire for low resistance at high frequency in switching power supplies. Engineers are designing such power supplies to switch at ever-higher frequencies to reduce the sizes and weights of transformers and other inductors. Switching frequencies of 200 kHz are not unusual, and some supplies switch as fast as 1 MHz. At these high frequencies, currents become concentrated at the surfaces of conductors (the skin effect), increasing the effective resistances and wasting energy. The waste can be reduced by using stranded wire instead of solid wire, but until now the diameter of the wire and the appropriate number of strands had to be selected by trial and error.

The only inputs required by the program are the switching frequency, the specified current, and the specified current density. First, the program calculates the skin depth as a function of frequency. It chooses a strand of standard-gauge wire, the radius of which closely approximates the skin depth. It calculates the total required cross-sectional area of bare wire from the ratio of the current to the current density. The number of strands is then calculated as that which has a total cross-sectional area close to the required area.

This work was done by Colonel W. T. McLyman of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-17279/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Stacked Metal Silicide/Silicon Far-Infrared Detectors

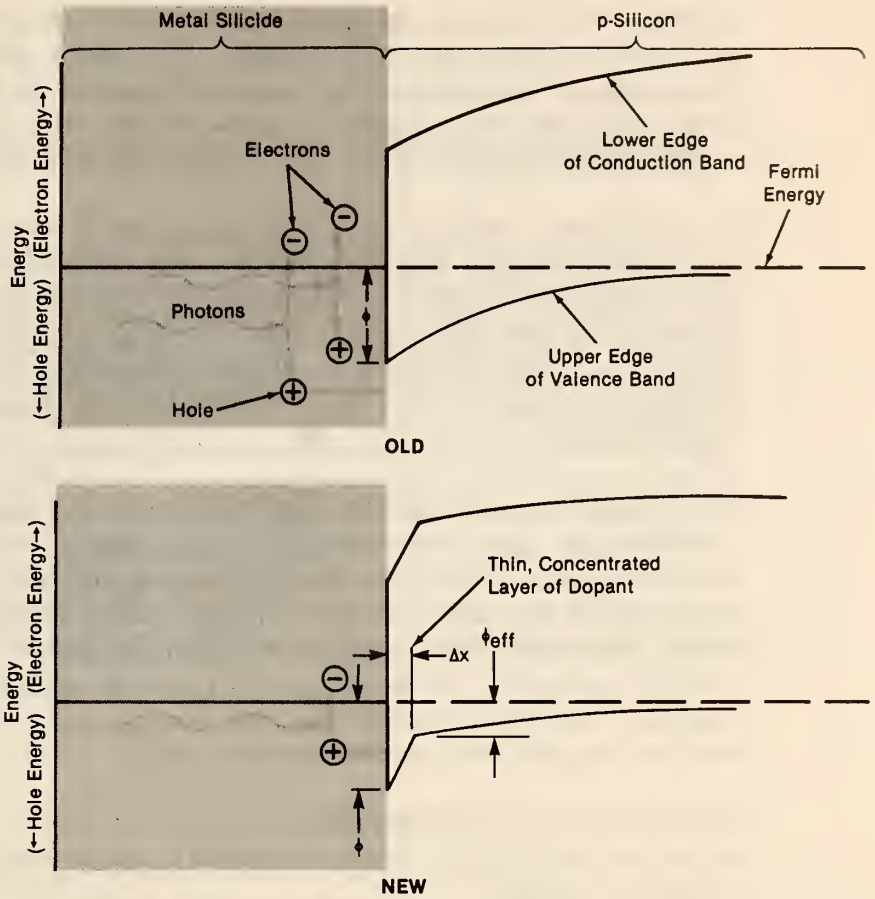
The long-wavelength limit would be extended.

Selective doping of the silicon in a proposed metal silicide/silicon Schottky-barrier infrared photodetector would increase the maximum detectable wavelength. Stacking the layers to form multiple Schottky barriers would increase the quantum efficiency of the detector. Detectors of the new type would enhance the capabilities of far-infrared imaging arrays.

In a conventional detector of this type, a Schottky barrier is formed at the interface between a PtSi or Pd_2Si contact and positively doped silicon, as shown at the top of the figure. Photons absorbed in the silicide near the interface produce holes, the maximum energies of which equal the photon energy. Holes of energy greater than the barrier height, ϕ, pass by the barrier and are collected in the silicon as photocurrent. The maximum detectable wavelength is the wavelength of photons of the minimum detectable energy ϕ.

In the proposed detector a thin layer of very high positive dopant concentration would be placed in the silicon at a small distance Δx from the interface. This layer would reduce the width of the peak in the Schottky barrier as shown at the bottom of the figure, permitting significant numbers of holes to tunnel quantum mechanically through the barrier. The tunneling would reduce the effective height of the barrier to a lower value, ϕ_{eff}. Thus, the maximum detectable wavelength would be increased to that of photons of energy ϕ_{eff}.

The quantum efficiency of a typical Schottky-barrier detector is only about 1 percent. If the device is made with multiple Schottky barriers, the quantum efficiency should be increased because each photon would then have multiple opportunities to photoexcite holes in the thin metal silicide layers. To realize an overall quantum efficiency of about 10 percent or better in a multiple-layer device, the metal silicide layers be thinner than about 10 nm; that is, substantially less than a mean-free-path length for the photoexcited holes. This assures that the holes have repeated opportunities of being collected at one of the interfaces before losing their energy by inelastic collisions.



A **Thin, Concentrated Layer of Dopant** would narrow the Schottky barrier, reducing its effective height from ϕ to ϕ_{eff}.

Detectors of the new type could be grown by molecular-beam epitaxy on silicon wafers that also contain very-large-scale integrated circuits. Thus, imaging arrays of detectors could be made in monolithic units with image-preprocessing circuitry.

This work was done by Joseph Maserjian of Caltech for **NASA's Jet Propulsion Laboratory.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL Refer to NPO-17194/TN

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FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

U.S. Navy Fact Sheet

Digital Lock-In Detector for Ultra-Low Level Noise Spectrum Analysis

A personal computer based digital lock-in detector was developed and used in ultra-low level noise spectrum analysis. The digital lock-in detector was integrated with a digital spectrum analyzer based on an Apple IIe computer to form a complete noise spectrum analysis system. This system is capable of analyzing noise signals much lower than internal amplifier noise.

In experimental electrical noise studies and similar areas, many signals are not measurable because they are lower than the internal amplifier noise. Especially at low frequencies, amplifier noises become overwhelming, due to the 1/f noise generated by the internal active devices. By using lock-in detection, the internal amplifier noise can be rejected. Low frequency noise signals are conventionally processed digitally and the use of a digital lock-in detector results in an all-digital system.

The digital lock-in detector developed here provides a highly attractive way for ultra-low level signal measurements. The results show that it is capable of detecting signals much lower than the internal amplifier noise. The lowest level which can be detected is determined by the components in the amplifier noise whose frequencies are close to the modulating frequency. The design of the detector guarantees the detection to be locked in, so correct results can be obtained. The digital method used here reduces the cost by tens of times for this kind of ultra-low level signal measurements.

FOR ADDITIONAL INFORMATION:
A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: AD-A198515/9/NAC
Price code: A02

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

New Technique for Measuring Waveguide Loss

Scientists in NIST/s Electromagnetic Technology Division, Boulder, Colo., have developed a new technique for measuring propagation loss in optical channel waveguides used in optical communication, signal processing, and sensor applications. The technique is based on photothermal deflection effect which employs a laser beam to probe extremely small temperature changes resulting from the absorption of light. Other techniques used currently to measure waveguide losses risk damage to the guide, require special material preparation, or are subject to a large uncertainty due to randomly scattered light. The new technique avoids these difficulties and is applicable to a variety of waveguide materials.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact Aaron A. Sanders, Division 724.02, NIST, Boulder, CO 80303; (303) 497-5341.

Energy

0356 Navy Installing First Gas Turbine Cogeneration System

0357 Center Promotes Solar Technology at Remote Sites

0358 Energy-Conserving Retrofit Audit for Single-Family Buildings

0359 Facility Assesses Geoelectric Methods for Oil/Gas Industry

0360 Photovoltaic Concentrator Cell Achieves Record Efficiency

0361 Economics, Efficiency of Insulation Without Chlorofluorocarbons

0362 Free-Piston Stirling Engines—These engines promise cost-effective solar-power generation.

0363 Improves Bipolar Separator for Lead Acid Batteries—The new separator would prolong battery life. (Licensing Opportunity)

Other Items of Interest

0372 Tribological Properties of Coal Slurries—A flocking agent (coal oil) in a coal/methanol slurry reduces wear.

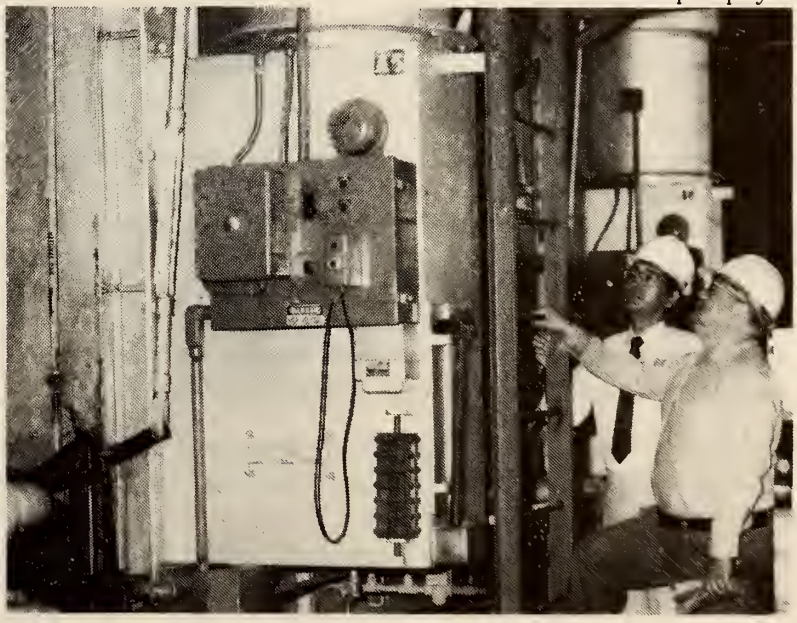
Navy Installing First Gas Turbine Cogeneration System

An 800-kilowatt (kW) gas turbine cogeneration system with a waste heat recovery boiler that produces electrical and steam (thermal) energy simultaneously is being installed at the Naval Construction Battalion Center, Port Hueneme, California.

Financed solely by the Navy, the $2.7 million site-specific facility should be operational sometime in 1989. The plant will capture exhaust heat (approximately 900 degrees F) escaping from the turbine and direct it in the boiler to generate steam at a rate of 6,500 pounds per hour. Additional steam (23,000 pounds per hour) will be supplied by a supplemental boiler fueled by natural gas.

Representatives of the Naval Civil Engineering Laboratory, Port Hueneme, said the new facility will supply about 10 percent of electrical and thermal power needed by the complex of 10,000 military and civilian employees. Additional electricity will be purchased from Southern California Edison Company, a commercial utility company. Presently, the base generates no electrical power.

The Navy's Cogeneration Program has identified major bases where the system would be economically feasible. When the 800-kW gas turbine is on line, an approximate annual savings of $300,000 should be realized with a simple payback period of four



COGENERATION TAKING OVER--This boiler, one of three built 34 years ago at the Naval Construction Battalion Center, Port Hueneme, California, will be replaced by the Navy's first gas turbine cogeneration system. Under construction, the site-specific facility will supply approximately 10 percent of needed electrical and thermal power.

years. Department of Defense representatives, supporting this significant energy-saving potential, said that by recapturing and using some of the waste energy normally discharged from an engine, a cogeneration system can reduce fuel requirements between 10 and 30 percent at a given site.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 131101/TN

Sandia National Laboratory

Center Promotes Solar Technology at Remote Sites

Engineers from Sandia National Laboratories are helping to bring solar electrical energy to people around the world who normally must rely on batteries or small gasoline generators or do without power supplies.

Among them are people on the Hopi Indian reservation of northeastern Arizona, in remote areas of Latin America, and at a wildlife refuge on a Pacific Ocean island.

These projects are among several under way by Sandia's Photovoltaic Design Assistance Center, which already has a string of similar programs to its credit in the U.S. and abroad. The center, operating under the aegis of the U.S. Department of Energy, works with U.S. groups and international agencies to solve special power-supply problems through the use of solar energy.

Formed to accelerate the use of photovoltaic technology where it is cost-effective, the Design Assistance Center helps educate potential users through consultations, system analysis and workshops.

The center also provides assistance on major projects to private industry, state and federal government agencies, and foreign concerns interested in using solar energy. This past summer, center experts met with Hopis on their reservation to discuss their model project that could result in up to 500 photovoltaic home systems being installed by 1990.

"We look for any project where it is cost effective and makes sense," says Gary J. Jones, supervisor of the Photovoltaic Systems Research Division at Sandia. "As an example, the military has thousands of small remote power uses for perimeter lighting and other applications where solar is more effective than extending an existing electrical grid system."

Photovoltaics, Jones notes, is now the power source of choice for the telecommunications industry, providing low levels of power at remote sites.

Jones sees the Design Assistance Center's role as critical to the transition from applications that are not yet commercial to a photovoltaic industry of the future that is decidedly economic. "Prices are dropping and systems are becoming more efficient. But to ensure a photovoltaics industry in the mid-1990s, you have to make inroads now. If you wait until prices drop, you won't be ready."

Jones and his staff operate the Design Assistance Center. They have worked with a number of military groups as well as other federal and state agencies. "We like situations where we can work with groups and show them how photovoltaics fits their needs; then, the use can be leveraged to other applications," Jones says.

The center has developed three popular booklets for users considering a photovoltaic project: Today's Photovoltaic Systems evaluates a number of existing photovoltaic projects and discusses details of their performance. Photovoltaics for Military Applications provides a step-by-step approach to identifying applications and procuring appropriate systems. Stand-Alone Photovoltaic Systems: A Handbook of Recommended Design Practices offers a simplified approach to sizing systems and discusses hardware selection, installation and maintenance. Specific examples of photovoltaic systems are presented, covering a range of typical applications.

The Design Assistance Center's role in developing photovoltaic systems overseas stems from the 1984 enactment of the Federal Renewable Energy Export Act. The act put Sandia in a position to encourage consideration of photovoltaic and other renewable energy forms overseas. Sandia receives guidance in this effort from the Committee On Renewable Energy for Commerce and Trade (CORECT), a group representing major federal agencies.

The center fills gaps between commercial solar concerns and potential users in many ways. "We're not replacing industry," Jones explains. "We will provide conceptual design, but when we get to a certain point, we'll back off and let our clients make intelligent, informed decisions, working with industry."

The design center continues to work with a variety of other clients, including several United Nations agencies, the Pan American Health Organization, the South Pacific Institute for Renewable Energy (SPIRE) and more than a dozen interested utility companies.

A remote Pacific atoll, Tern Island has been operated maintenance-free on photovoltaic power for about six months now. The system installed there has also saved the high cost of purchasing and transporting diesel fuel to the island, according to the Fish and Wildlife Service's Acting Regional Director Wally Steucke.

"We're really working on two levels," says Sandia's Jones. "One level is learning about photovoltaic applications for the future that are not yet cost effective. But a large number of remote power applications are cost effective now and that's the second level."

Two years ago, working with the Organization of American States, the center became involved in presentations, training and the direction of several pilot refrigeration projects. Vaccine refrigerators powered by photovoltaic systems were installed in Guatemala, Honduras, and El Salvador. The units have proven successful, especially in terms of ease of operations. The design center continues to help host-governments in efforts to obtain additional refrigerators.

Other types of programs are now being looked at, Jones explains. "It costs millions of dollars to run electric grids to villages in developing countries. We are finding that one photovoltaic module and two 20-watt lights at a community center can have a major impact on lifestyle. You can do that without running power lines. Decentralized power productions will be a growing market for photovoltaics."

FOR ADDITIONAL INFORMATION: Public Information Division, Code 3161, Department of Energy, Sandia National Laboratories, Albuquerque, NM, 87185-5800; (505)844-4207. Refer to announcement 23, No. 7.

Department of Energy

Technology Application

Oak Ridge National Laboratories

Energy-Conserving Retrofit Audit for Single-Family Buildings

Space heating is the principal energy consumer in single-family buildings for most parts of the country. Many utilities, government agencies, and individuals are interested in reducing household expenditures for energy by improving the energy efficiency of single-family buildings. One of the major problems facing all those interested in improving home-heating energy use is selection of the energy-conserving retrofits that save the most energy at the least cost.

The ORNL report, *Field Test Evaluation of Conservation Retrofits of Low-Income Single-Family Buildings: Combined Building Shell and Heating System Retrofit Audit,* describes a retrofit audit that solves a number of the problems with typical audits. Savings from retrofits depend on a house's characteristics, its occupants, its heating system, the climate, and fuel cost. This report presents methods to estimate savings for 13 building shells and gas-heating-system retrofits that use actual building characteristics.

This report describes a method for calculating the ratio of retrofit savings to cost (*B/C*); *B/C* is a useful common basis for comparing the economic advantages of various energy-conserving retrofits. The report suggests using *B/C* for selecting retrofits for installation. For example, homeowners can choose to install retrofits with a *B/C* above a certain value or to install retrofits as they can afford them, starting with the highest *B/C* retrofits. Utilities and government agencies that give energy-conservation retrofits to qualifying households can extend this approach by selecting retrofits by *B/C* for retrofits on a pool of houses. This approach results in more effective use of retrofit funds because more money is spent on houses that can achieve substantial savings while less is spent on houses that already use space-heating energy efficiently.

Some pairs of retrofits act to save the same energy; these are called interacting retrofits. The audit also uses *B/C* as a tool for allocating savings among interacting retrofits. For example, adding insulation to a building shell and installing a more efficient heating system are interacting retrofits. Together, they save less energy than the sum of the energies each would save if it were installed with the other absent. The audit accounts for interactions between retrofits in

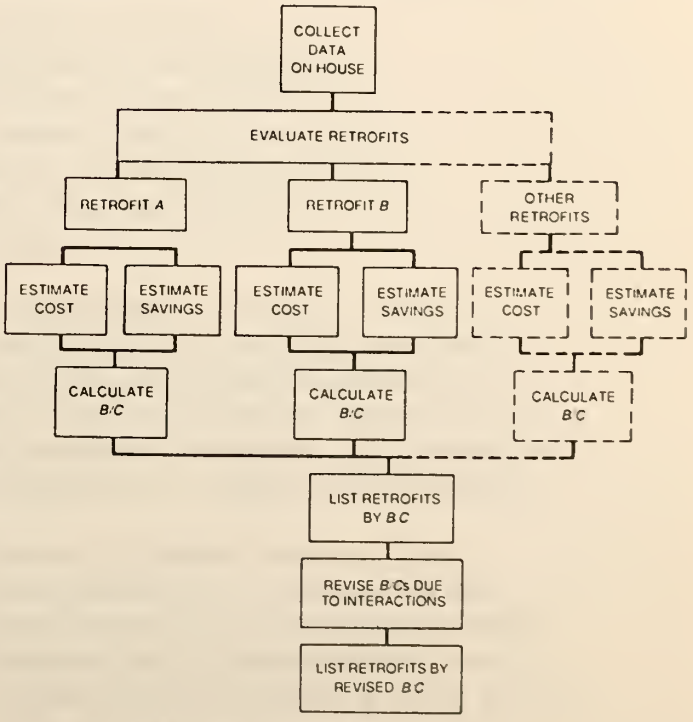


Fig. 1. Savings-to-cost (*B/C*) audit process for an individual house.

estimation of retrofit savings and uses *B/C* to allocate those savings rationally between interacting retrofits.

The approach described in this report was designed for use by government-agency and utility-retrofit programs, but it is applicable to retrofit decisions on individual homes as well (Fig. 1). Additional retrofits can be added without changing the structure of the audit; however, because collecting data for the audit can be time-consuming, it may be advantageous to restrict the number of retrofits to those that are often useful.

L. N. McCold, *Field Test Evaluation of Conservation Retrofits of Low-Income, Single-Family Buildings: Combined Building Shell and Heating System Retrofit Audit,* ORNL/CON-228/P3, Oak Ridge National Laboratory (May 1987).

L. N. McCold, J. A. Schlegel, and D. C. Hewitt, "Technical and Practical Problems in Developing and Implementing an Improved Retrofit Audit," pp. 7.146-7.159 in *Proceedings from the Panel on Social & Health Factors,* American Council for an Energy-Efficient Economy, Washington, D. C., August 1986 (*Proceedings for the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Santa Cruz, Calif.,* Vol. 7).

Additional information:

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Department of Energy

Technology Application

Sandia National Laboratory

Facility Assesses Geoelectric Methods for Oil/Gas Industry

A new facility at Sandia National Laboratories is helping researchers assess techniques for monitoring oil and gas recovery processes. Completed this spring, the geoelectric simulation facility (GSF) could eventually lead to improved geophysical diagnostic techniques.

The GSF is being used first to model surface electrical potential (SEP) technology, a technique the researchers believe may be useful for mapping underground recovery processes-such as steamfloods and hydraulic fracturing-as they occur.

Researchers in Sandia's Advanced Technology Division say the new facility should be the most accurate one ever built for scale modeling of SEP technology. Although it has been around for years and is used commercially to help locate ore bodies, SEP technology has not become a practical technique for the oil and gas industry. The researchers believe the GSF will help them determine whether SEP and some similar techniques can become practical for the energy industry.

For energy applications the idea is to apply electrical current to the well casing extending down into the ground. After the current travels down the casing and back up through the ground, electrical measurements are taken at numerous points surrounding the well and then recorded. The recorded SEP patterns vary according to formation types, temperatures, and discontinuities (faults and fractures, for example) through which the current passes.

After studying the recorded pattern, geophysicists try to infer the location (particularly the lateral geometry) of energy recovery processes under way at the time. The objective is to determine whether the processes are occurring efficiently, for example, whether injected steam is reaching the desired areas or is channeling as a result of variations in reservoir properties. This information could be used to help engineers make adjustments to improve process efficiency.

The problem, according to Advanced Technology Division supervisor Paul Hommert, is that "Engineers haven't known exactly how to interpret the data gathered in the field experiments. We have never had validated models to predict the response we should get. So, in the past few years we have been doing some fundamental research to determine if surface electrical potential is viable for the oil and gas industry."

The primary part of the facility is a hemispherical tank about 3-1/2 feet (1.1 meters) in diameter. Use of an electrolytic fluid (de-ionized water and potassium chloride solution) in the tank allows researchers to mimic the resistivities of underground formations.

Discontinuities in the geology can be simulated by emplacing small, coated metallic strips or tiny balloons filled with an electrolytic fluid of contrasting resistivity into the tank. These discontinuities tend to modify the current paths and consequently to change the electrical potential measured on the surface.

Tom Bickel, primary designer and operator of the GSF, believes it is a major improvement over other simulators. "Their main problem is the interference caused by the physical boundary. Researchers have been trying to model processes that take place underground, where there is no boundary, inside a tank that obviously must have a boundary."

"Up until now," Bickel continues, "modelers used the boundaries as a conductive electrode to complete the electrical circuit. The tank boundary has affected the problem. We modified the boundary so it no longer does that, thereby allowing a much better simulation of field conditions."

"The facility will allow us to do a lot of things that no one has ever been able to do," Hommert says. "We can now also look at ways to optimize electrical techniques-downhole current injection as opposed to surface current injection, for example."

The tank consists of 60 identical copper triangles that are 1 mil thick. The triangles were assembled over a sturdy aluminum form and bonded together in a way that electrically isolates each triangle from the others. After the bottom side of the copper hemisphere was reinforced and supported, the aluminum form was removed. A thin gold coating on the inside of the tank protects the copper, which would otherwise go into solution when current is applied.

Each triangle has a wire connected to its back side, which leads into a computer-controlled interface that controls the triangles' resistance to ground. The computer allows the resistance to be set from 1 to 410 ohms in one-tenth ohm steps.

FOR ADDITIONAL INFORMATION: Public Information Division, Code 3161, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800; (505)844-4207. Refer to announcement 23, No. 7.

Sandia National Laboratory

Photovoltaic Concentrator Cell Achieves Record Efficiency

Scientists at Sandia National Laboratories have achieved a 31 percent solar-to-electric conversion rate with a new photovoltaic concentrator cell. The rate is the highest efficiency ever recorded by any photovoltaic device.

By comparison, commercially available concentrator cells are currently 18 to 20 percent efficient. Recent experimental work with similar multijunction, or compound crystalline cells, had recorded results up to 26.6 percent.

The new cell, described as a mechanically stacked multijunction solar cell, takes advantage of advances in solid state technology from Varian Associates Inc. and Stanford University as well as from Sandia's own Photovoltaic Cell Research Division. It is made up of gallium arsenide and silicon crystalline cells (from Varian and Stanford, respectively) in a layered, or stacked, arrangement. Peak efficiency for the record-breaking cell came at a light intensity level of 35 to 50 W/cm^2, which is the equivalent of 350 to 500 suns.

Gallium arsenide gaining momentum

Photovoltaic technology converts sunlight directly to electricity through a solar cell. While silicon cell technology continues to be an important area of research, the examination of other materials, including gallium arsenide, has also gained momentum in recent years.

Concentrators multiply the energy of the sun focused on a cell by use of a lens or other optical device set into a housing with the cell. Optical technology is now availahle to concentrate up to 1,000 suns on a single concentrator cell. To generate significant amounts of electric current, cells and concentrators are grouped into modules.

Sandia was directly involved in the development of the two cells used in the record-establishing effort, explains Dan Arvizu, supervisor of Sandia's Photovoltaic Cell Research Division. The gallium arsenide cell was developed under contract with Sandia by Varian Associates, Palo Alto, Calif. The silicon cell was developed in cooperation with Stanford University, in California.

A multijunction solar cell is made up of two or more cells with different light acceptance characteristics (handgaps) permitting it to ahsorb a broader part of the solar spectrum than a single cell. In the 0.317 cm^2 Sandia cell, light from the blue end of the spectrum is absorbed and converted to electricity hy the upper cell. Other light frequencies are reflected or pass through to the lower cell, which operates largely from the red portion of the spectrum.

In the latest Sandia multijunction effort, the Varian top cell achieved an efficiency of 27.2 percent. Several hottom cells were tested in the lab, with peak efficiencies of the stacked cell ranging from 29.5 to 31 percent. The Stanford-developed cell recorded the highest bottom cell efficiency, 3.8 percent. Bottom cell efficiencies are lower hecause that cell receives only a small part of the total spectrum that enters the top cell.

James Gee, who constructed the record-setting stacked concentrator cell, examines an earlier concentrator module at Sandia. The new cell will ultimately be part of such a module, which concentrates the equivalent of 1,000 suns onto each cell.

Latest generation of stacked cells

Sandia began working on the gallium arsenide-silicon combination in 1984, recording an efficiency of 24.7 percent in early attempts. Analysis at that time clearly showed efficiencies of more than 30 percent were possible, Arvizu says. Under the direction of Sandia engineer James Gee, two additional generations of stacked cells have been developed and tested, the latest of which resulted in the present laboratory demonstration.

The new cell breaks the 30 percent barrier in efficiency, attaining a goal of the U.S. Department of Energy's (DOE) five-year research plan. That plan calls for an experimental multijunction concentrator with 30 percent efficiency hy this year. A subsequent program goal calls for the cells to be grouped and installed in a high efficiency module.

Module efficiencies are expected to be less than those of the cell alone because of losses in the electrical and optical parts of the module. Later experimental cell efficiencies will be pushed to 35 percent under the DOE plan and ultimately to their expected limits of near 40 percent.

Making a packaged cell for field testing in modules is as important or more important than further improvements in cell efficiency, says Sandia's Gee. But still better cell efficiency results are expected, he says. A bottom cell with 5 to 6 percent efficiency, combined with a gallium-arsenide top cell in the 29 to 30 percent efficiency range would achieve the longer-term DOE goal of 35 percent, he notes.

FOR ADDITIONAL INFORMATION

Public Information Division,
Code 3161,
Department of Energy,
Sandia National Laboratories,
Albuquerque, NM 87185-5800
(505) 844-4207
Refer to announcement 23, No. 6

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Economics, Efficiency of Insulation Without Chlorofluorocarbons

Two of the most efficient insulating products used in new building construction today are polyurethane and extruded polystyrene rigid foam insulation; both contain chlorofluorocarbons--CFCs. During the foam manufacturing process, CFCs are used to form gas cells or bubbles in the foam making it an excellent insulator. However, there is evidence that CFCs can break down the Earth's ozone layer, and their manufacture and use may be curtailed. In a study for the Department of Energy, NIST researchers looked at the cost-effectiveness and potential energy consequences of using expanded polystyrene (EPS) and fiberglass--neither contains CFCs. They found that both insulation materials typically cost less than most CFC-containing foams. But since they contain air bubbles instead of gas bubbles, they do not insulate as efficiently. And, because more of the materla is needed to achieve the same thermal performance, there may be an increased in cost if walls or roof areas must be expanded to accommodate the thicker insulation.

FOR ADDITIONAL INFORMATION: A report, Technical and Economic Analysis of CFC-Blown Insulations and Substitutes for Residential and Commercial Construction, is available from the National Technical Information Service, Springfield, VA 22161, for A04 prepaid. Order by PB88-243399/NAC.

NASA Tech Brief
National Aeronautics and Space Administration

Free-Piston Stirling Engines

These engines promise cost-effective solar-power generation.

A report describes two concepts for Stirling-engine systems for the conversion of solar heat to electrical energy. Long considered a highly efficient candidate for the dynamic conversion of energy in spacecraft, whether solar-powered or nuclear-powered, the free-piston Stirling engine is now recognized as one of the most promising technologies for meeting the U.S. Department of Energy goals for performance and cost for terrestrial electrical-energy sources.

The report discusses free-piston Stirling engines. Invented in 1962 by William Beale, this type of engine differs from the kinematic Stirling engine invented by Robert Stirling in 1816 in that it has only two moving parts, has noncontacting gas bearings, and can be hermetically sealed. It offers the potential for high reliability and long life.

The goal for one of the conceptual systems is to generate about 25 kW of electrical power from Sunlight and feed it to a utility grid at a cost of $300/kW for the engine and alternator system. The system would have a productive lifetime of 30 years.

Both conceptual designs specify a liquid-metal heat-pipe receiver in addition to a free-piston Stirling engine. One concept incorporates a linear alternator to convert the energy to electricity directly. The other concept generates electrical power indirectly, sending pressurized hydraulic fluid to a hydraulic motor coupled to a rotating alternator. Both concepts will be evaluated, and one will be selected for final design, assembly, and testing.

This work was done by Richard K. Shaltens of **Lewis Research Center**. *Further information may be found in NASA TM-88897* Price Code A03 *"Advanced Stirling Conversion Systems for Terrestrial Applications."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

LEW-14558/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Improved Bipolar Separator for Lead Acid Batteries

The new separator would prolong battery life.

A new design for a bipolar separator would consist of a polyethylene plate 0.01 in. (0.25 mm) thick and glass mats 0.01 in. (0.25 mm) thick, bonded to both faces of the plate. Loosely woven scrims of chemical glass 0.01 in. (0.25 mm) thick, bonded to the glass mats, hold the active material. The glass mats and the scrims are attached by glue. The new separator design would reduce the loss of the active material, thus prolonging battery life.

This work was done by Wally E. Rippel and Dean B. Edwards of Caltech for **NASA's Jet Propulsion Laboratory**.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)], to the California Institute of Technology. Inquiries concerning licenses for its commercial development should be addressed to

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Refer to NPO-15241/TN

Jet Propulsion Lab.
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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Engineering

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0376 Fast Detection of Breaks in Ducts—Breaks in optical fibers reveal failures in duct walls.

0377 Optical Sensor of High Gas Temperatures—A contact pyrometer resists effects of heat, vibration, and moisture.

Other Items of Interest

0383 Parts Digitizing Systems Three Dimensional Automatic Reverse Engineering

0388 Soft-Thresholding Image Analysis

0391 Nickel-Iron Aluminides for Advanced Coal Conversion Systems (Licensing Opportunity)

U.S. Army Fact Sheet

Composite Embedded Fiber Optic Sensor for Measurement of Structural Vibrations

Control of flexible space structures is a problem that extends to several initiatives in the development of orbiting platforms. In particular, SDI platforms will require a very high degree of pointing accuracy and stability, ~10-6 radians. A number of ventures involving large satellites and other strategic defense platforms, such as Spaced Based Laser and Space Based Radar, will employ designs that incorporate flexible appendages, such as lightweight mirrors and antennas, whose operation depends upon a carefully controlled microgravity environment, i.e. minimal accelerations. Pointing accuracy must be maintained in the presence of self-induced platform motion (tracking and retargetting) and impact from foreign objects.

Future space structures will make abundant use of composite laminates using advanced resins reinforced with high stiffness materials, such as graphite and boron. To minimize the problems associated with vibration of these large, lightweight structures, new concepts in active control are needed. A critical element of such a control system is an integrated measurement system that will sense the state of deformation or strain with adequate bandwidth to resolve and null the energetic vibration modes.

A technique has been proposed for vibration control that uses embedded fiber optic sensors and an integrated control system to measure the distributed strain in structural elements and provide active feedback for force transducers. Fiber optic sensors have been shown to offer unique advantages in sensing strain, temperature, and other quantities in harsh environments. The state of strain of a structural element with embedded fibers can be sensed over a broad area of the structure, since the optical fibers are laid up in the structure along with the composite fibers. The necessary control-related measurements can be made continuously while the structure is undergoing a vibrational excitation. Potential advantages of fiber optic strain sensors embedded in composite materials include:

Structural advantages of composites plus potential for rugged embedded sensors through laminated fabrication techniques.

High resolution, wide bandwidth, low power consumption, EMI resistance, and flexible geometry possible with fiber optic sensors.

Synergism of fiber optic sensors and advanced control theory to achieve an integrated structural control system.

Possibility of efficient optical signal processing of data from numerous sensors in a large scale advanced system.

The goal of a research program was to demonstrate the feasibility of building a composite-embedded, fiber optic sensor, active, structural control system for strategic defense platforms. The results of this study confirm the viability of a fiber optic strain sensor to detect and measure low amplitude composite element vibrations. The fiber optic strain sensor was successfully embedded within the sub-scale composite element and measurements of the induced vibrations using the interferometric sensors followed the response predicted by theory with good accuracy. Also, control analysis was performed on methods to constrain the vibrations.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: AD-A194270/NAC

Price code: A03

U.S. Army Research

U.S. Army Natick RD&E Center, Natick, MA 01760

Development of a High Stacking Strength Container

The project entitled Develop A High-Stacking-Strength Container was undertaken to develop a corrugated container that would withstand high compression loads at standard and high temperature/high humidity conditions.

The need for improved container stacking strength stems from changes in the nature of the unit packaging within the container. Traditional unit packaging has been cans or glass bottles. These cans or bottles would carry the weight of package contents in inventory stacks and during shipment. The role of the corrugated container was truly that of a container, to keep the contents together during shipment. In recent years unit packaing has shifted more to paper and plastic which provide little or no compression strength. The source of stability in inventory stacks and in loads during shipment has therefore shifted to the outside container, the corrugated box. When the outside container is not capable of supporting multiple pallet loads in inventory stacks, pallet support systems (racks) are required. These systems are expensive, take up space, and restrict handling.

In this project, the potential of chemical additives was examined as an alternative to additional fibre. While it has been understood for some time that additives to paper may provide considerable strength increases in the linerboard, chemical additives may also create brittleness, cracking, and bonding problems. Some chemicals present toxicity concerns in manufacturing, use, and disposal. The project objectives required any chemicals used ot be food grade and limited add-on level to 10% of the combined board to minimize scoreline cracking.

The linerboard was impregnated with a mixture of sodium silicate and koalin clay. The saturant was approximately 62% water, 34% sodium silicate, and 4% koalin clay. The treatment levels were targeted at between 10% and 14% add-on of the basis weight. The corrugating medium was not treated. The resin add-on resulted in a 7% increase in the weight of the combined corrugated board.

Doublewall corrugated containers, measuring 20" x 12" x 10", were manufactured from this treated linerboard and a wet strength corrugating medium, which was not impregnated, and quantities of the containers were submitted to an independent laboratory for testing.

Results of tests showed that the compression strength of the container was increased by approximately 150% under standard conditions and more than 200% under tropic conditions after treatment with the chemical compound.

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U.S. Army Fact Sheet

U.S. Army Industrial Engineering Activity, Rock Island, IL 61299-7260

Technologies Evaluated to Produce Fine Size RDX

The introduction of low vulnerability ammunition (LOVA) has greatly increased the demand for sub-20-micron nitramines. This project evaluated four technologies for production of these very fine particle sizes. These were fluid energy milling (FEM), pump grinding, chemical grinding (complexation) and direct recrystallization. The results show FEM to be the best alternative. In addition to requiring the least capital investment ($3.7 million) and having the lowest operating cost (58 cents/lb), FEM is the only process that is field proven on a production scale. Also, for 5-micron size particles, only FEM and chemical grinding can produce particle sizes that low.

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Oak Ridge National Laboratories

Evaporator Control System

Precise control of evaporator concentrate concentrations is, at times, needed in industry to avoid plant upsets and to meet product specifications. In systems with three component concentrations (ternary mixtures), the problem of obtaining concentration control is complicated because the absolute concentration of each component cannot be obtained in the evaporator process alone. Engineers at the Oak Ridge Y-12 Plant have developed a computerized system that determines concentrations of a ternary system (salt, acid, and water) based on measurements of solution density, specific conductivity of a diluted sample, and temperature. Evaporation and back-dilution processes have been highly automated, which has provided dramatic improvement in concentration control. This system could be used for other applications by repeating the laboratory analysis for the appropriate solutions.

In ternary-mixture evaporator-control applications, the ratio of two components can be controlled in the evaporator with a dilution by a third component in a process immediately downstream. One component must be capable of being boiled off while the second component remains in the concentrate. To obtain the desired ratio, there must be an excess of the volatile component so that the concentrate at the proper ratio will have component concentrations higher than that desired in the product. The back-dilution process provides adjustment of concentrations to the desired level.

For the industrial system developed at the Y-12 Plant, measurements are made using a vibrating "U-tube" densitometer, an electrodeless conductivity cell, and temperature elements (Fig. 1). Because specific conductivity is not monotonic in the range of interest for the acid used, the conductivity stream is automatically diluted to extend the useful range of the system. Regression equations for density and conductivity in terms of component concentrations and temperatures were obtained based on laboratory results. Equations for the component concentrations were obtained by solving the regression equations. Component concentrations are then determined on-line from measured data using derived equations.

The computer-based control system uses a proportional-integral-derivative algorithm to provide control of the concentration ratio under

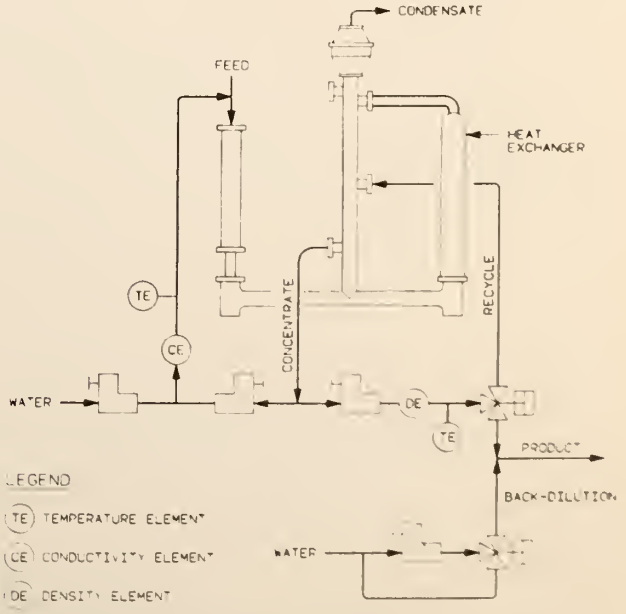

Fig. 1. The evaporator control system.

normal conditions. Water back-dilution is used to obtain specified product concentrations. This dilution is performed in the line close to where the concentrate is removed from the evaporator to prevent freezing of concentrate as it cools. Water dilution flow rate is controlled by a feed-forward algorithm.

Under certain conditions, it is not possible to use the normal system controls to provide a product with the specified concentrations. For example, in the case of feed with a high salt concentration, the system limits the concentrate's salt to prevent freezing of the evaporator. When the feed has insufficient acid, the system controls the salt concentration and specifies the amount of acid to be used in the back-dilution process in place of water. In the latter case, a product that is within specifications can be made.

The system also provides automatic startup and shutdown of the evaporator operation. Shutdown of the evaporator is done in a controlled fashion to ensure that the solution in the evaporator does not freeze when it cools. Automatic shutdown can be initiated by the operator or by the system when tank-level-alarm limits are exceeded.

In an industrial application, this system provided a precision of 6% (one standard deviation) in the product salt concentration, which was a factor-of-10 improvement over the previous operation. Acid precision was 10% (one standard deviation), which was a factor-of-3 improvement.

Additional information:

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NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Making Building-Related Economic Decisions

Whether you are building a house or a skyscraper, many decisions have to be made concerning investments in the structure and its components. Questions might include: Are fire sprinklers cost effective? Which floor finish-carpet, tile, wood-is most cost effective? What is the most economically efficient level of insulation? But often the answers are not clear cut and a decision must be made based on a "best guess." A new report by economists in the NIST Center for Computing and Applied Mathematics can help alleviate some of the uncertainty and risk in making building decisions. The report describes a variety of risk analysis techniques and describes advantages and disadvantages of each. The American Society for Testing and Materials is using the report as the basis for a new standard practice.

FOR ADDITIONAL INFORMATION:
Techniques for Treating Uncertainty and Risk in the
Economic Evaluation of Building Investments (NIST SP 757)
is available from NTIS, Springfield, VA 22161; (703) 487-4600.
NTIS order number: PB89-129522/NAC
Price Code: A05

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Crash-Energy-Absorbing Composite Subfloor Structure

A weighted-sum method accurately predicts the energy-absorption capability.

A simple method of predicting the energy-absorption capability of a composite subfloor beam structure has been developed. The method is based upon the weighted sum of the energy-absorption capabilities of constituent elements of a subfloor beam.

The subfloor beam structure of a helicopter is composed of a grillwork of longitudinal and transverse beams. Noncrash loads carried by the beam structure typically consist of reaction loads from the fuselage skin, frames, bulkheads, and seats. Energy is absorbed in a helicopter during a crash primarily by controlled stroking of the landing gear and subsequent crushing of the subfloor beam structure. This beam structure typically consists of integrally stiffened, honeycomb-sandwich, unstiffened, or sine-wave beams.

In this study, the subfloor beam structure was used to describe and verify the method of predicting the energy-absorption capabilities of structural elements. It was hypothesized that the crash-energy-absorption capability of a structural element is the weighted sum of the energy-absorption capabilities of its characteristic elements. This hypothesis assumes that the structure progressively crushes before catastrophic failure.

The constituent elements of the beam can be either straight or curved sections. Tube specimens with circular or square cross sections were used in this study to determine the energy-absorption capabilities of the characteristic elements of the beams. Empirical data on the absorption of energy in circular- and square-cross-section tube specimens were used to make predictions. The procedure was demonstrated on three kinds of subfloor beams (see table). The measurements and predictions agreed within 7 percent in all three cases. This procedure is general and applicable to a wide range of subfloor beam structures.

Description of Specimen	Energy-Absorption Capability	
	Predicted (N-m/g)	Experimental (N-m/g)
Graphite/Epoxy Sine-Wave Beam	56	54
Polymer/Epoxy, Circular-Cross-Section-Tube-Stiffened Beam	30	28
Graphite/Epoxy, Rectangular-Cross-Section-Tube-Stiffened Beam	41	42

Weighted-Sum Predictions of crash-energy-absorption capabilities are compared with measured values.

This work was done by Gary L. Farley of the U.S. Army Aviation Research and Technology Activity for **Langley Research Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center
Refer to LAR-13697/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Stable and Oscillating Acoustic Levitation

Sample stability or instability is determined by levitating frequency.

The degree of oscillation of an acoustically levitated object along an axis of a levitation chamber can be controlled by varying the frequency of the acoustic driver for that axis above or below the frequency of the corresponding chamber resonance. The stabilization/oscillation technique can be applied in normal Earth gravity, or in the absence of gravity, to bring an object quickly to rest at a nominal levitation position or to make the object oscillate in a desired range about that position.

Typically, the problem is to control vertical oscillations about the equilibrium position in a gravitational field (see Figure 1). The restoring-force parameter (effective spring stiffness) for the oscillation varies with the acoustic pressure, the frequency, and the vertical position. Thus, the spring stiffness is modulated by the oscillation. As a further complication, the resonant frequency varies slightly with the position of the sample, and the finite time required to reach steady-state pressure in an acoustic resonator results in dephasing.

The combined effect of these phenomena during a number of cycles of the oscillation can be to pump energy into the oscillations (increasing the oscillation amplitude),

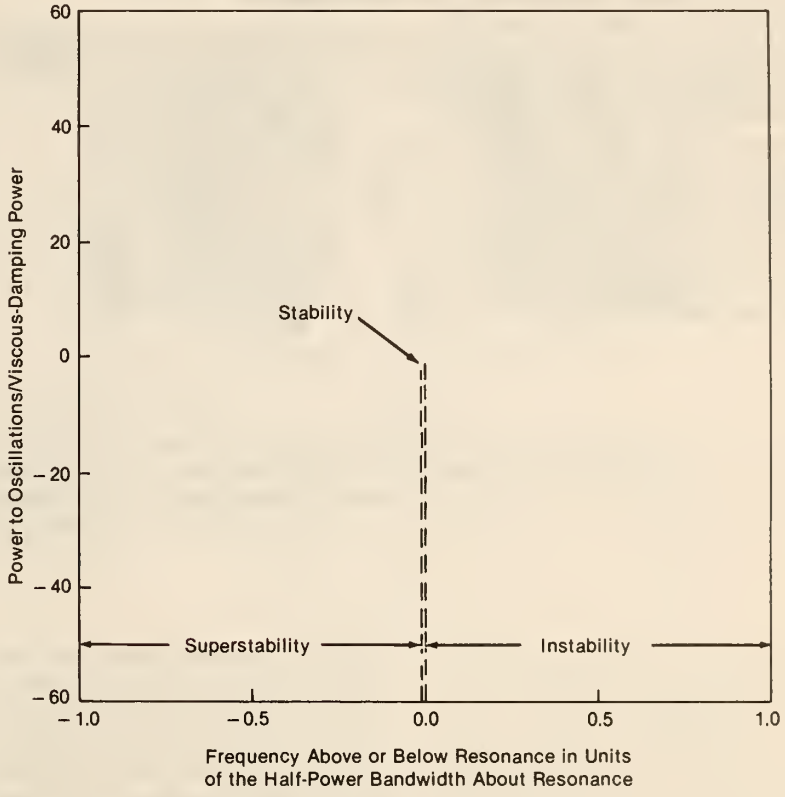

Figure 2. **Vertical Oscillations Grow or Are Damped** in a representative system at a rate determined by the frequency relative to the resonant frequency of the chamber. The parameters of the system are the following: normal Earth gravitation (980 cm/s^2), acoustic pressure 160 dB, relative bandwidth of resonance = one one-hundredth, and oscillation amplitude = one-tenth the height of the chamber.

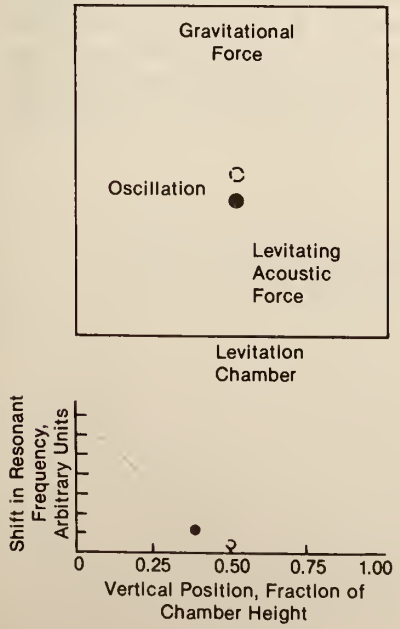

Figure 1. A **Levitated Object** oscillates vertically about a nominal or equilibrium position as though it were suspended on a spring. The chamber resonant frequency varies slightly with the vertical position of the sample.

to withdraw energy from the oscillations (decreasing the oscillation amplitude), or to do neither. If the effect is to contribute just enough energy to balance the energy lost to viscous drag, then the oscillation amplitude stays the same. If the effect is to withdraw energy, then it acts in concert with viscous drag to damp the oscillations quickly. If the effect is to add energy, then the oscillations grow.

Calculations and experiments show that the acoustic field pumps energy into, does not exchange energy with, or withdraws energy from the oscillations when the levitating frequency is above, at, or below the resonant frequency of the chamber, respectively (see Figure 2). (Because of the viscous drag, the required levitating frequency for the onset of growth of oscillations is slightly above the resonant frequency.) If the actual levitating frequency is fixed at a value slightly above this onset frequency, the oscillations grow until the nonlinear competing effects raise the onset frequency to the actual levitating frequency.

This work was done by Martin B. Barmatz of Caltech and Steven L. Garrett of Naval Postgraduate School for **NASA's Jet Propulsion Laboratory.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-16896/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Portable Liquid-Injecting System

A lightweight gun provides controlled, adjustable volumes of liquid.

A portable injecting-gun system dispenses a predetermined amount of liquid at moderately high pressure. Although most dispensing and metering systems are large and heavy, the new system can be carried on a tool belt (see figure).

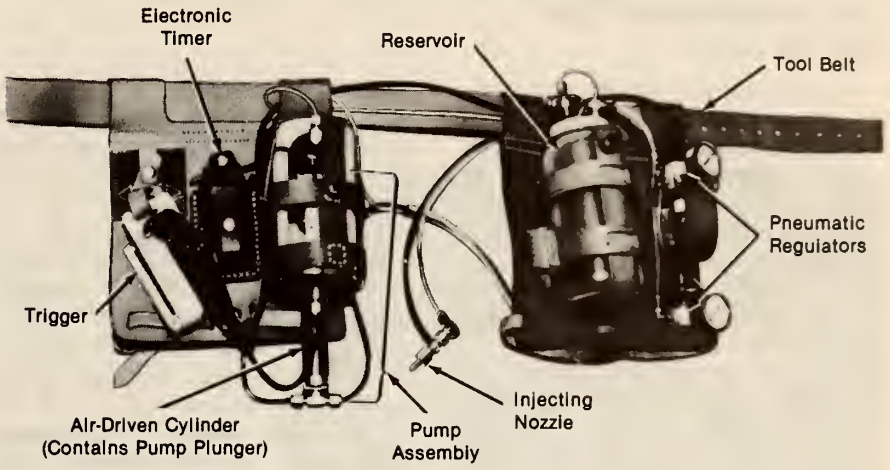
The system includes an injecting nozzle, a pump driven by an air cylinder, a four-way valve to control the air, an electronic timer, a reservoir of liquid, pneumatic regulators, and a trigger assembly. The operator inserts the nozzle into a hole in the workpiece. Pressing the trigger directs air to the aft end of the pump. The air activates the timer and drives the pump plunger, dispensing the liquid through the nozzle into the hole and simultaneously providing a small purging flow of air to aid the entry of the liquid.

A buzzer in the timer sounds 4 seconds after the trigger has been pressed, signaling the operator that the proper amount of liquid has been dispensed. Releasing the trigger directs air to the forward end of the pump, pushing back the plunger and stopping the flow of liquid and purge air through the nozzle.

The volume of injected liquid can be varied from 1 to 4 cm^3. A threaded collar on the air cylinder of the pump lets the operator make the adjustment easily.

Two check valves — one on the intake side of the pump and one on the outlet end — control the direction of liquid flow. A third check valve at the injecting nozzle minimizes the spillage of liquid and prevents the purge air from entering the liquid line. When liquid is being injected, pressure closes the intake check valve and opens the outlet check valves at the pump and the injecting nozzle. When the pump plunger retracts, it creates a suction that closes the outlet check valves and opens the inlet check valve so that liquid can refill the pump chamber.

When the 1-liter liquid reservoir is depleted, the operator can quickly replace the empty bottle with a full one. The bottles are equipped with quick-disconnect fittings, to prevent spillage when they are changed, and with relief valves, to protect them in case they are overfilled or overpressurized.



A **Tool Belt Holds Components** of the liquid-injecting system. The pump and four-way valve are combined in a nylon housing. They are connected to the injecting nozzle and the other components by polyvinyl tubing.

This work was done by T. Shuck, F. Chin, and M. Hansen of Rockwell International Corp. for **Johnson Space Center**.

MSC-21308/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Tribological Properties of Coal Slurries

A flocking agent (coal oil) in a coal/methanol slurry reduces wear.

A report describes a study of the tribological properties of coal/methanol slurries with a pin-on-disk tribometer. Coefficients of friction, rates of wear of the steel pin, and morphological studies of the worn surfaces were conducted on pins and disks of AISI 440C HT (high-temperature) stainless steel and M-50 tool steel, both of which are used as bearing steels. Coal slurries have been considered as replacement fuels in terrestrial oil-burning facilities and as possible fuels for future aircraft turbine engines. The rates of wear of metallic components through which the slurries flow could limit such practical applications.

In a series of runs, a pin and a disk of each steel were slid against each other dry, in methanol, in a slurry of fine coal particles in methanol, and in a similar slurry to which a coal-oil flocking agent was added. The hemispherical tips of the pins, each 0.467 cm in radius, were pressed with a force of 9.8 N against the 6.3-cm-diameter disks, which were rotated at 100 rpm to obtain a linear sliding speed of 0.26 m/s.

The coefficients of friction measured with methanol alone and with the two slurries containing methanol were nearly the same; all were in the range of 0.16 to 0.19. With 440C HT steel, the rates of wear for the coal/methanol slurries without and with the flocking additive were 23×10^{-15} and 15×10^{-15} m^3 per meter of sliding, respectively. The corresponding rates with M-50 steel were slightly higher. When the methanol was allowed to evaporate from the slurry with the flocking additive, the coefficient of friction dropped to 0.10 and the rate of wear dropped to 4×10^{-15} m^3 per meter of sliding. The coal slurry (with and without the flocking additive) induced cracking and spalling on the worn surface of the M-50 but not on that of the 440C HT steel, indicating that the type of steel selected for use with slurries could be very important.

This work was done by Robert L. Fusaro of **Lewis Research Center** *and Dale L. Schrubens of Texas A&I University. Further information may be found in NASA TM-89930 [N87-24565], [price code: A03] "Tribological Properties of Coal Slurries."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

LEW-14739/TN

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Oak Ridge National Laboratories

Nondestructive Testing with Pulsed Eddy Currents

Pulsed eddy currents contain a wide band of frequency components that can be used to identify many different material properties. However, certain materials and configurations limit the usefulness of conventional testing systems. Researchers in ORNL's Metals and Ceramics Division have developed pulsed eddy-current equipment that can make accurate nondestructive evaluations that were previously impossible (Fig. 1). One very great advantage of this new system is that most of the changes required for different types of inspection can be made with simple software changes instead of the more difficult and expensive hardware changes needed with conventional multiple fixed frequency systems.

One application of this new equipment is the bore-side examination of the ferromagnetic tubing used in the heat exchangers and steam generators of nuclear reactors. Eddy currents cannot penetrate deeply into ferromagnetic materials unless the operating frequency is very low, but small flaws are hard to detect at such low frequencies. A large, brief pulse of electric current through a small coil inside the tubing can magnetically saturate the material so that its permeability becomes effectively like that of air; eddy currents can then penetrate at the high frequencies needed to detect small flaws. The voltage picked up by another coil wound around the saturating coil can detect the field of the pulsed driving current as well as the eddy currents induced in the tubing and modified by

Fig. 1. Eddy current pulser module, which contains a large capacitor to supply the pulse energy, track-and-hold modules to measure the pickup voltage at computer-controlled intervals, and a microcomputer to handle the data. The module is the interface between the eddy-current coil and the desk-top computer that controls the experiment. The operator holds one of the very small probes in her right hand and one of the large pulsed magnetic saturation probes in her left hand.

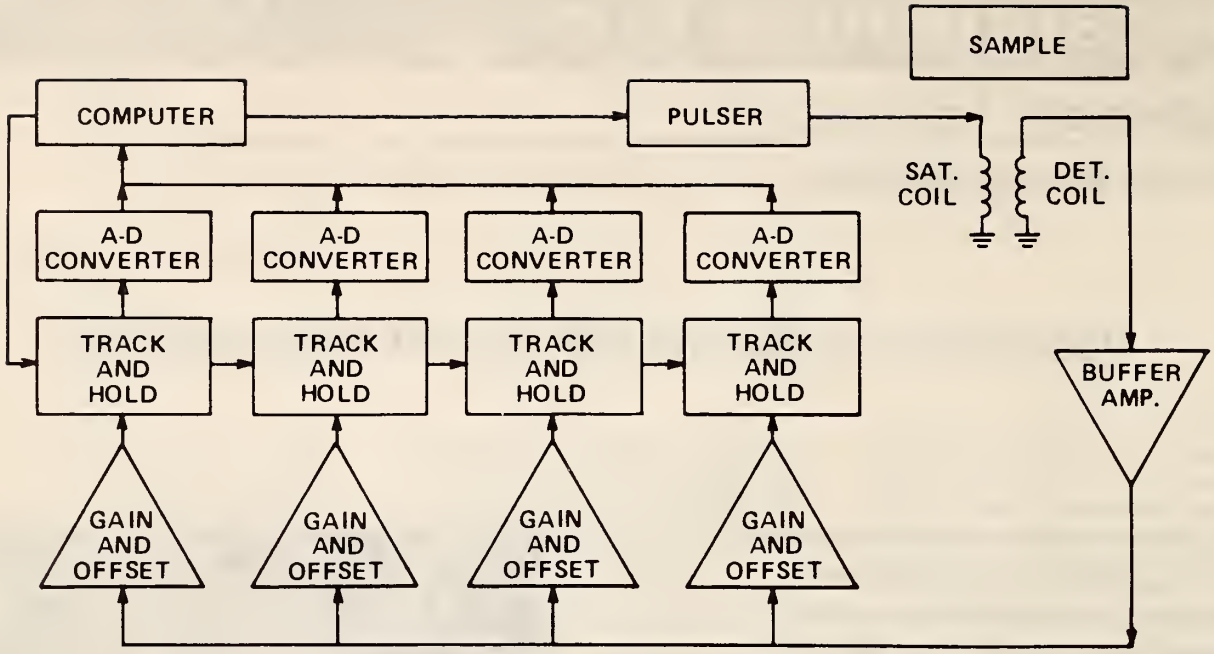

Fig. 2. Block diagram of a computer-controlled instrument to measure voltages at certain time intervals.

the presence of any flaws or other unusual conditions (Fig. 2).

Other applications include the examination of very small samples or very poor conductors (such as graphite and some ceramics) that require the use of frequencies higher than those at which commercial instruments can make accurate phase measurements. For example, a sample of small, thin-walled stainless steel tubing (3.7 mm diam and 0.13 mm thick) was examined using an external coil (about 1 mm diam) driven with square wave pulses at a repetition rate of 3.2 MHz. Flaws smaller than 0.01 mm were readily detected on both the inside and the outside of the tubing.

Additional information:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

C. V. Dodd and W. E. Deeds, *Eddy-Current Inspection of Ferromagnetic Tubing Using Pulsed Magnetic Saturation,* ORNL-6305, Oak Ridge National Laboratory (July 1986).

C. V. Dodd et al., *Pulsed Eddy-Current Inspection of Thin-Walled Stainless Steel Tubing,* ORNL-6408, Oak Ridge National Laboratory (September 1987).

C. V. Dodd and W. E. Deeds, "Multiparameter Methods with Pulsed Eddy Currents," pp. 849-54 in *Review of Progress in Quantitative Nondestructive Evaluation,* ed. Donald O. Thompson and Dale E. Chimenti, Plenum, New York, 1987.

Oak Ridge National Laboratories

Pulsed-Aerosol Analyzer

A new system for measuring pulsed aerosols may find widespread application in the pharmaceuticals, minerals, plastics, and chemicals industries. This system determines the quantity of aerosol particulates within a sampled stream regardless of the stream's homogeneity or whether it is present continuously or intermittently. The particulate cloud is mixed by drawing the aerosol stream through two orifices mounted in the sensor unit. The flow rate and concentration of the particulate stream are measured simultaneously.

Flow rate is determined by measuring the pressure drop across one of the orifices. Particulate concentration is determined by using an infrared light-emitting diode/phototransistor combination (LED/PT) in a backscattering mode. The LED/PT is mounted immediately downstream of the orifices. Pressure drop and backscattered light signals are sent to an analog-to-digital conversion board mounted in a personal computer, where they are digitized, scaled, multiplied, and integrated by the software package (Fig. 1). The integrated product is

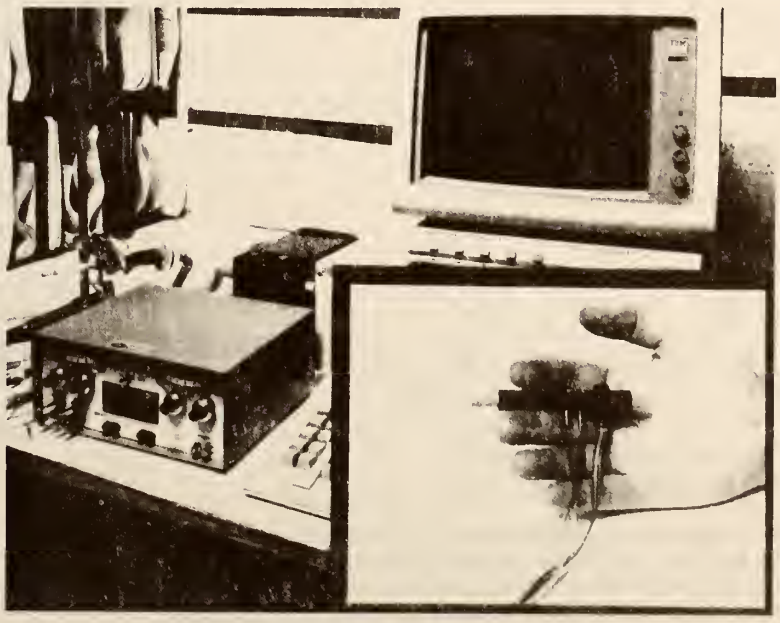

Fig. 1. The pulsed-aerosol analyzer. An infrared light-emitting diode/phototransistor combination is mounted immediately downstream of the orifices *(inset)*.

proportional to the mass of the particulates, regardless of the variation in concentration, flow, or particulate-cloud homogeneity. This system provides (1) data output on a pulse-by-pulse basis, (2) summations of various parameters over the duration of the monitoring cycle, and (3) a record of both mass concentration and flow profiles.

The pulsed-aerosol analyzer can be used to determine pulsed airborne particulate mass deliveries at concentrations from 80 mg/m^3 to 100 g/m^3. The initial application of this system has been as a human smoking dosimeter, the only device capable of determining the mouth exposure of humans to the particulate matter of cigarette smoke. As such, this device provides information heretofore unavailable to researchers. Potential applications include monitoring processes such as the blending and mixing of dry ingredients and the coating of products with waxes, oils, or powder dispersions. This device can also be used as a diagnostic tool in malfunctioning particle-delivery systems, providing flow-profile and particulate-concentration information simultaneously.

Additional information:

Office of Technology Applications
Martin Marietta Energy Systems, Inc.
P.O. Box 2008
Oak Ridge, TN 37831-6257

Telephone: (615) 574-4192; FTS 624-4192

R. A. Jenkins and T. M. Gayle, "An Instrumental Cigarette Smoke Monitor Designed for the Direct Measurement of Smoke Particulate Matter Generated in Human Smoking Studies," *Behav. Res. Methods, Instrum., & Comput.* **16**(3), 263-67 (1984).

NASA Tech Brief
National Aeronautics and Space Administration
John F. Kennedy Space Center, Florida

Licensing Opportunity

Dual-Cantilever-Beam Accelerometer

Sensitivity to velocity changes along the beam axis is reduced.

A dual-cantilever-beam accelerometer reduces the spurious signal due to acceleration along the beam axis. It therefore gives more-accurate and more-nearly-linear readings of transverse acceleration. Like ordinary single-cantilever-beam accelerometers, the new device is simple and inexpensive.

The beams are mounted on opposite sides of a base and hold masses at their ends (see figure). Strain gauges on the beams are connected in a bridge circuit.

When the sensor is subjected to transverse acceleration (in the y direction), both beams deflect equally. If the device is also accelerated along the beam axis (the x direction), the magnitude of deflection of the forward beam is increased, while that of the rearward beam is decreased. The bridge circuit used in conjuction with the strain gauges produces an output that represents the average strain of both beams. Thus, the effect of acceleration along the beam axis is suppressed electrically, effectively making the device less sensitive to acceleration along the x axis.

This work was done by Emmitt A. Reynolds of **Kennedy Space Center** *and Frank H. Speckhart of the University of Tennessee. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center Refer to KSC-11235/TN

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Kennedy Space Center, FL 32899
(305) 867-3017
Patent Counsel: James O. Harrell
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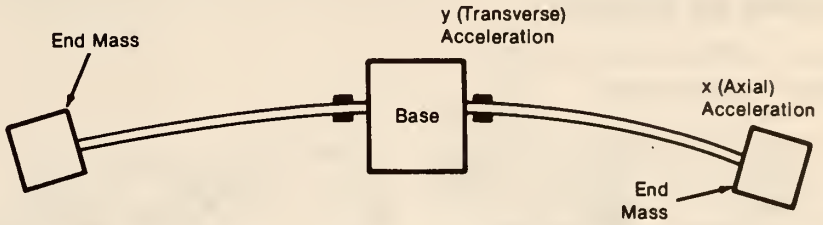
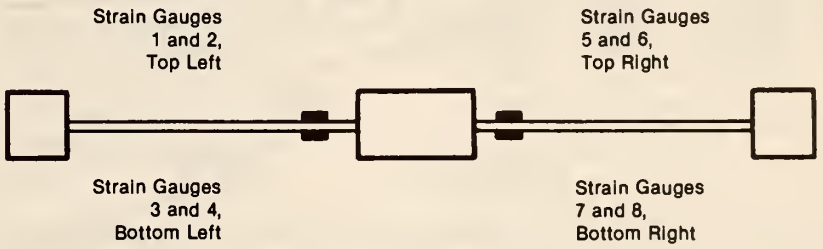
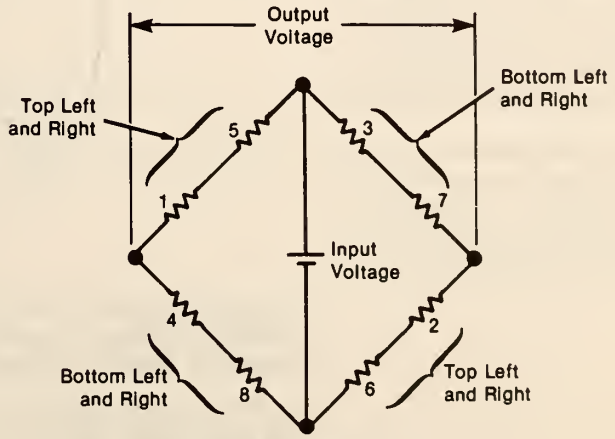


ACCELEROMETER UNDER ACCELERATION


Strain Gauges 1 and 2, Top Left
Strain Gauges 5 and 6, Top Right
Strain Gauges 3 and 4, Bottom Left
Strain Gauges 7 and 8, Bottom Right

ACCELEROMETER AT REST



ELECTRICAL CONNECTION FOR STRAIN GAUGES

The **Weighted-End Cantilever Beams** of the accelerometer are deflected equally by acceleration in the y direction. When there is acceleration to the right as well as up or down, the right beam is deflected more, while the left beam is deflected less. The bridge circuit averages the outputs of the strain gauges that measure the deflections, so that the cross-axis sensitivity of the accelerometer is reduced.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

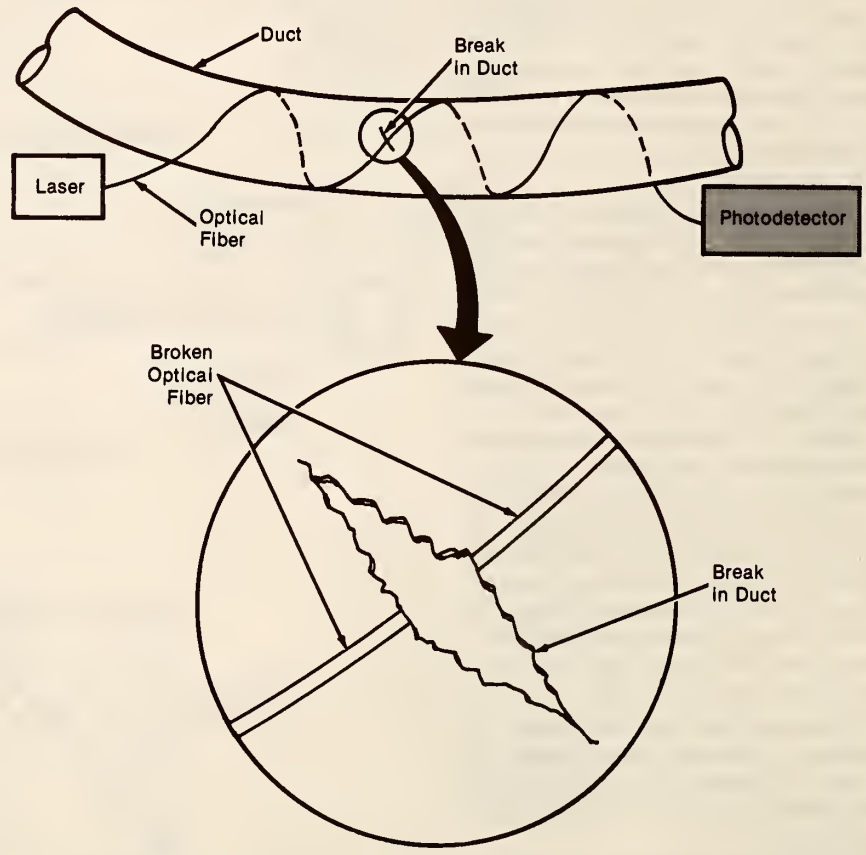
Fast Detection of Breaks in Ducts

Breaks in optical fibers reveal failures in duct walls.

A group of optical fibers would give almost instantaneous indication of imminent engine failure by monitoring the integrity of high-pressure lines and ducts, a concept suggests. The fibers would be wrapped helically around a duct or pipe and bonded to it (see figure). A crack in the wall would produce a crack in one or more fibers, interrupting the transmission of light. The interruption could be used to command a shutdown of the engine or other system to minimize damage.

Because a typical receiving photodetector at the end of a fiber can respond to changes in the light level in less than a microsecond, shutdown would be triggered faster than it is in the current method of detecting line failure that compares engine-sensor readings with "red-line" limits. Moreover, the location of the fault can be determined by measuring the travel time of light pulses reflected from the fiber break by use of time-domain reflectometry. The function of the optical fibers would not be adversely affected by electromagnetic interference.

To guard against false alarms, a voting scheme could be used to trigger a shutdown. If, for example, four out of five fibers fail suddenly, an engine shutdown could be commanded. Alternatively, the voting scheme could be applied to the time-domain-reflectometry technique to confirm the location of the failure: if three out of five fibers fail within one-fourth in. (6 mm) or another specified distance, the engine could be shut down.



A **Group of Optical Fibers Wrapped** around a duct (only one of the many fibers is shown here) carries light beams from lasers to photodiodes. A break in the duct would break the fiber bonded to it, interrupting the path of the light between the laser and the photodetector.

This work was done by Matthew A. Smith and Ray C. Delcher of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29274/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

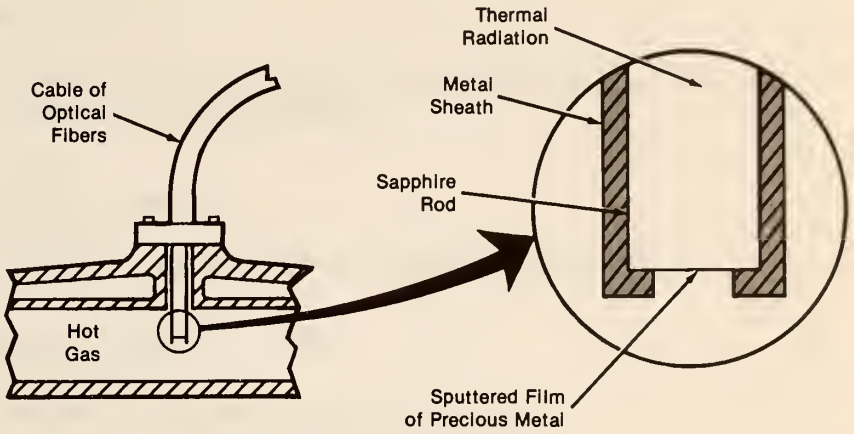
Optical Sensor of High Gas Temperatures

A contact pyrometer resists effects of heat, vibration, and moisture.

An optical-fiber temperature sensor withstands hot engine-exhaust gases. The sensor is more reliable than thermocouples or resistance-temperature devices, the wires of which are subject to heat- and vibration-induced failure. It is more accurate than conventional pyrometers, which are prone to errors caused by shifts in the emissivities of gases with changes in temperature and composition.

The new sensor consists of a shielded sapphire rod with a sputtered layer of precious metal on its end (see figure). The metal layer acts as a blackbody. It emits radiation that has a known dependence of spectral distribution with the temperature of the metal and, consequently, with the temperature of the hot gas flowing over the metal. A fiber-optic cable carries the radiation from the sapphire rod to a remote photodetector.

This work was done by Arthur J. Hill of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.* *MFS-29316/TN*



The **Optical-Fiber Sensor Projects** into a stream of hot gas. The temperature of the metal film on the tip of the sensor is essentially that of the gas. An optical-fiber cable conducts thermal radiation from the film to a photodetector.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Environmental Science & Technology

0378 Industrial Boiler Low NO_x Combustion Retrofit Cost Algorithm Development

Software

0379 Three-Dimensional Finite-Element Model of Water Flow Through Saturated-Unsaturated Media

Testing & Instrumentation

0380 Concentric Micronebulizer for Direct Sample Insertion

Other Items of Interest

0420 Method of Generating Chemiluminescent Light

United States
Environmental Protection
Agency

Air and Energy Engineering
Research Laboratory
Research Triangle Park, NC 27711

Research and Development

EPA

Project Summary

Industrial Boiler Low NO_X Combustion Retrofit Cost Algorithm Development

This report documents the development of low NO_X burner (LNB) retrofit cost algorithms for industrial boilers. Also included are cost algorithms for overfire air (OFA) and low excess air (LEA) systems. Costs (in 1985 dollars) are estimated for new systems as well as retrofit applications. The boiler sizes evaluated include those with capacities ranging from 10 to 1300 million Btu/hr(*) heat input.

Included are summaries of the data sources and the methodology used to generate the cost algorithms. The approach to acquire detailed cost data and the available literature sources used as the basis for the retrofit cost estimates are described. Also summarized are the cost algorithm development and the boiler/burner design used to estimate costs on a per burner or overfire air port basis.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Industrial Combustion Emissions (ICE) model has been developed to assess the costs of NO_X controls applied to existing stationary combustion sources. However, the cost information in the model needs substantial improvement to provide accurate assessments. Computerized algorithms for low NO_X burners have been developed for large utility-size boilers, but not for industrial-size boilers. Due to major differences in boiler size, number of burners, and control complexity between utility and industrial boilers, separate costs need to be developed for low NO_X burners applied to industrial-sized boilers.

Procedure

A capital costing format for retrofit NO_X combustion modification controls (for pulverized coal and gas/oil applications) was developed for use by boiler and burner manufacturers. Model boiler sizes of 25, 100, 200, 500, and 1300 million Btu/hr were selected as being representative of industrial boiler applications. Detailed costs for low NO_X burners, overfire air, and low excess air systems were to be estimated for estimated NO_X reductions of 50, 25, (40 for gas and oil), and 10%, respectively.

Since no detailed cost data were obtained from manufacturers in this study, cost algorithms had to be developed based upon cost information available in the literature. Major sources of costs were presented as overall capital costs for a given size unit. To convert these costs to a per burner (or per overfire air port) basis, various utility survey reports and manufacturer contact reports were utilized to develop estimates

(*) For readers more familiar with the metric system, 1 Btu/hr = 0.29 W.

of the number of burners as a function of boiler size. Other cost data sources include past EPA studies evaluating NO_x controls for utility and industrial boilers. Also, some costs from previous communications with burner manufacturers were utilized.

Results

To estimate the number and size of burners as a function of boiler size, information about several coal-fired utility and industrial boilers was compiled. In the industrial boiler size range, there is a wide range of burner sizes. For coal-fired industrial boilers of capacities from 100 to 1300 million Btu/hr heat input, burner sizes generally range from about 25 to 125 million Btu/hr. Based on this, the default values in the cost algorithms for the number of burners are as follows:

Industrial Boiler Size Range, 10^6 Btu/hr	No. of Burners	Potential Burner Arrange-ments, row x column	No. of OFA Ports (de-fault value)
100 - 500	4	2x2	2
500 - 750	6	3x2 or 2x3	3
750 - 1000	8 - 9	4x2, 2x4, or 3x3	4
1000-1300	12	4x3 or 3x4	4

These design bases allow the conversion of utility low NO_x burner and OFA total system capital costs to a per burner or per OFA port basis. Total capital costs were first converted to a per unit basis. Then, these unit costs were fit to a logarithmic function of unit size. Total industrial boiler system costs can then be determined by multiplying these unit costs by the number of low NO_x burners or OFA ports required for that particular industrial boiler size. For oil- and gas-fired boilers, typically there is a single burner in boilers smaller than 200 million Btu/hr heat input. For larger boilers, the burner pattern is estimated to be the same as that for pulverized coal.

Another capital cost impact of NO_x controls is the effect of staged combustion (both low NO_x burners and overfire air) on packaged oil- and gas-fired industrial boilers. The tight fireboxes and resulting high heat release rates of the larger packaged industrial boilers limit the NO_x reduction and steam production capabilities of those systems.

To keep operating heat release rates at a maximum level consistent with the use of effective NO_x controls, a new packaged industrial boiler equipped with a low NO_x burner or overfire air would have to be built physically larger to maintain the same capacity. Many existing packaged boilers would need to have their maximum firing rate reduced (i.e., capacity derate). Capacity derating is an alternative that also can be applied to new packaged boilers if a physically larger unit could not be shipped (e.g., due to railcar space limitations).

Preliminary analyses indicate that boiler capacity derate is roughly a linear function with boiler size, ranging from no derate at 75 million Btu/hr up to about 40 percent derate at 200 million Btu/hr. For new oil- and gas-fired boilers in this size range, the incremental capital cost of a larger boiler must be added to the capital costs of low NO_x burner and overfire air NO_x controls. For retrofit applications, the derate cost impact was addressed in terms of capacity replacement and NO_x reduction performance: for derate greater than 15%, additional capacity was estimated at full NO_x reduction performance; at derate less than 15%, no replacement capacity was required (resulting in variable NO_x reduction performance).

Essentially no detailed data available on the operating costs associated with the retrofit of NO_x controls to utility and industrial boilers: no additional labor, no additional maintenance, no fuel penalty for low NO_x burners or OFA, and no fuel savings for LEA.

The total annualized costs are the sum of the annual O&M costs and the annualized capital charges. The annualized capital charges include the payoff of the capital investment. The annualized capital charges include the payoff of the capital investment (capital recovery), general and administrative costs, taxes, and insurance. The capital recovery cost is based on the equipment life, real interest rate, and total capital cost. For this analysis, a 10% real interest rate and a 15-year equipment life are assumed. This translates into a capital recovery factor of 13.15%.

Kevin L. Johnson is with Radian Corp., Research Triangle Park, NC 27709.
***Larry G. Jones** is the EPA Project Officer (see below).*
The complete report, entitled "Industrial Boiler Low NO_x Combustion Retrofit Cost Algorithm Development," (Order No. PB 88-239 074/AS; Cost: $12.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Oak Ridge National Laboratories

A Three-Dimensional Finite-Element Model of Water Flow Through Saturated-Unsaturated Media

3DFEMWATER is a three-dimensional finite-element model developed at ORNL for modeling the flow of water through saturated-unsaturated media. This model can be used to study the transport of dissolved constituents in a subsurface flow system, taking into account the system's velocity field, pressure distribution, and moisture content. 3DFEMWATER is unique in its flexibility and versatility in modeling a wide range of real-world problems.

In nature, water movement is a three-dimensional problem: it occurs in all directions under saturated-unsaturated flow conditions. However, most subsurface flow models for saturated-unsaturated media are limited to addressing one- or two-dimensional problems. 3DFEMWATER is a verified three-dimensional model of water flow through saturated-unsaturated media that describes naturally occurring or artificially disturbed flow systems. 3DFEMWATER can model completely saturated, completely unsaturated, or partially saturated and partially unsaturated flows. It can be applied to confined or unconfined aquifer regimes, and it provides spatially continuous solutions.

The specification of boundary conditions is the most difficult and intricate task in groundwater flow modeling. From a physical point of view, boundary conditions may be described as a soil-air, soil-soil, or soil-water interfaces. 3DFEMWATER contains four mathematically prescribed physical boundary types that are applied to suit the prevailing conditions:

- Dirichlet, for soil-water interfaces such as streams and lakes;
- Neumann, for the bottom of the media where natural drainage takes place;
- Cauchy, for surface-water bodies with known infiltration rates into subsurface media; and
- variable (where either Dirichlet or Cauchy may prevail) to account for rainfall and evapotranspiration.

In real-world problems, the recharge and pumping from rainfall and artificial withdrawals are likely to be time-dependent and distributed over the region of interest. The infiltration rate from the bottom of surface-water bodies into subsurface media depends on the depth of water, which varies with time. Furthermore, on the air-soil interface, the rainfall is intermittent and of varying intensity, resulting in transient total fluxes if the soil is capable of taking all the throughfall. 3DFEMWATER can deal with these aspects simultaneously.

3DFEMWATER contains several special features. For example, by including off-diagonal hydraulic conductivity components, the model can be applied to anisotropic and nonuniform media. When certain sets of system parameters (such as hydraulic retention and hydraulic conductivity) are variable, the rate of numerical convergence is very slow; for that reason, an overrelaxation technique is given as an option to speed up

numerical convergence. In addition, two options, successive subregional block iteration and successive point iteration, are included to greatly reduce computer memory requirements and computational time. Finally, automatic resetting of the time step size is built into 3DFEMWATER to facilitate calculations involving abrupt changes in external conditions.

Additional information:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

G. T. Yeh, *3DFEMWATER: A Three-Dimensional Finite Element Model of Water Flow Through Saturated-Unsaturated Media,* ORNL-6386, Oak Ridge National Laboratory (August 1987).

G. T. Yeh, *FEMWATER: A Finite Element Model of Water Flow Through Saturated-Unsaturated Porous Media, First Revision,* ORNL-5567/R1, Oak Ridge National Laboratory (August 1987).

Concentric Micronebulizer for Direct Sample Insertion

A powerful and versatile analytical tool results from combining high performance liquid chromatography (HPLC) techniques with inductively coupled plasma-atomic emission spectroscopy (ICP-AES). This combination is especially well-suited for determining elemental concentrations present in air pollution and biochemical samples.

HPLC and ICP-AES instruments are usually coupled by using a pneumatic nebulizer; the nebulizer receives the compounds separated by the HPLC and converts them to an aerosol required for ICP-AES detection. However, conventional nebulizers leave a large volume of dead space between the HPLC and the ICP-AES detector. This results in broad, overlapping data peaks that are difficult to interpret.

To improve the technique, Ames Laboratory researchers have invented a micro-concentric nebulizer that nearly eliminates the dead-volume. It also introduces 100 percent of the mist into the plasma, making it nearly 100 times more efficient than existing nebulizers.

These advantages are the result of an innovative design which consists of two concentric glass tubes; the end of the outer tube is tapered inwardly to an orifice. There is an annular spacing between the inner and outer tubes at the orifice. As a liquid sample flows through the inner tube, argon gas is simultaneously pumped into the annular space between the inner and outer tubes. At the orifice, the high velocity argon gas comes into contact with the liquid flowing from the inner tube and produces an aerosol that can be introduced directly into the plasma.

Literature: K. E. LaFreniere, V. A. Fassel, and D. E. Eckels, "Elemental Speciation Via High-Performance Liquid Chromatography Combined with Inductively Coupled Plasma - Atomic Emission Spectroscopic Detection: Application of a Direct Injection Nebulizer," *Analytical Chemistry* 59, 879 (1987).

Patent/License Status: U.S. Patent No. 4,575,609. CETAC Technologies, Inc., of Ames, Iowa, has obtained marketing rights from DOE and is currently marketing this item.

Potential Applications/Spinoffs: Environmental, biochemical analysis.

For More Information on this Technology: Contact Daniel E. Williams, Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, Iowa 50011 (515)294-2635.

AL 88-02

Manufacturing, Machinery & Tools

0381 Cut-Off Tool Adapter

0382 National Institute of Standards & Technology Establishes PDES Testbed

0383 Parts Digitizing Systems Three Dimensional Automatic Reverse Engineering

0384 Quick-Disconnect Valves for Modular Fluid Systems—Maintenance would be facilitated and loss of fluid minimized.

0385 Seal for Precooling a Turbopump—A diaphragm reduces misalignment. (Licensing Opportunity)

0386 Service Lives of Restored Bearings—Rebuilt units should last almost as long as new ones.

Testing & Instrumentation

0387 Coordinate Measuring at FERMILAB

0388 Soft-Thresholding Image Analysis

Technology Application

Oak Ridge National Laboratories

Cut-Off Tool Adapter

The cut-off tool adapter was developed to adapt a quick-change grooving and cut-off system to the round boring bars on many currently used turning machines. This device can be fitted directly onto the round boring bars on turning machines, using commercially available self-gripping, quick-change carbide inserts and cut-off blade insert holders. It can do various cut-off, part-off, and grooving operations (Fig. 1).

This new tool is quieter, safer, and more efficient than conventional designs. Its use has significantly reduced noise levels and vibration. The tool's design allows chips to flow away from the cutting edge rather than collecting there, making the tool safer. Its use eliminated one machine setup and one part movement, which resulted in more efficient operation.

This system eliminates the need for multiple adapters to accommodate the various tools required in production. The quick-change inserts and blades allow for a tool-change-time savings of about 75% over conventional cemented or brazed-tip square-shank lathe tools. During the first year of use, this system saved about

Fig. 1. The cut-off tool adapter. This device replaces conventional block-type boring-bar holders and eliminates the need for multiple holders.

$50,000 beyond the cost of conversion. The advantages of this system over those currently used are (1) creating a more rigid setup in less time, (2) allowing for tool-height adjustment, and (3) eliminating the need for multiple holders. Because of the tool-height-adjustment feature, conventional contact tool setters can be used. Its broad applicability ensures its dramatic impact on the metal-turning industry.

Additional information:

Office of Technology Applications
Martin Marietta Energy Systems, Inc.
P.O. Box 2008
Oak Ridge, TN 37831-6257

Telephone: (615) 574-4192; FTS 624-4192

No further documentation is available for this technology.

Navy Manufacturing Technology

Automated Manufacturing Research Facility

National Institute of Standards & Technology
Formerly the National Bureau of Standards (NBS)
U.S. Department of Commerce, Gaithersburg, MD 20899

National Institute of Standards & Technology Establishes PDES Testbed

As the initial step in fulfilling its commitment to serve as the central focus for the development and testing of the PDES (Product Data Exchange Specification) standard, NIST has established a National Testbed for PDES at the AMRF. Experience gained at the AMRF on the requirements for factory automation standards and the facility itself put NIST in the ideal position to assume this role.

The testbed will be vital in meeting the DOD Computer-Aided Acquisition and Logistic Support (CALS) Program's critical requirement for a neutral product data definition for weapon systems' parts that can be transferred to DOD as part of the final deliverable of a procurement.

IGES, developed by a committee chaired by NIST, has served as the first generation standard for transferring electronic descriptions of manufactured parts among different vendor's proprietary CAD systems. However, recent demands for solids modeling, configuration control, fully computer-interpretable data, and interactive access by cooperating users has led to the need for PDES. The new standard is under development by voluntary standards organizations, industry, and government. An Interagency Task Group including Army, Navy, and Air Force personnel is spurring it on. DOD wants to implement PDES as quickly and effeciently as possible. However, implementing PDES will require serious technical effort. Implementations must be tested as they are built to uncover problems and inconsistencies in the various definitions. If vendors implement PDES inconsistently (due to different interpretations), DOD's goal won't be met.

Experienced researchers working in a testbed environment can identify potential problems and suggest clarifications and interpretations of the standard. Work in the AMRF on manufacturing data preparation has already developed a product part model consistent with the expected PDES standard. AMRF researchers are testing to determine the effectiveness of this part model as the information needed by the manufacturing applications in the facility. As PDES is developed, this effort will be expanded.

The National PDES Testbed will play a major role in testing the validity and completeness of PDES' manufacturing data as well as in demonstrating the practicality of the data in an operational environment.

NIST's National Computer and Telecommunications Laboratory (formerly the Institute of Computer Science and Technology) has joined the Center for Manufacturing Engineering in this effort.

For Additional Information:

To discuss this effort further, contact:
Cita Furlani
AMRF Project
Building 220—Room A-127
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(301) 975-3543

NAVY Manufacturing Technology Program

Parts Digitizing Systems Three Dimensional Automatic Reverse Engineering

Up-to-date technical data does not exist for many of the hundreds of thousands of parts used in military operations. When spares or replacements are required for these insufficiently documented parts, a process known as "reverse engineering" is used to generate dimensions for manufacture. Traditionally a tedious, time consuming, and error prone manual operation, reverse engineering is being revolutionized by an automated 3-D Parts Digitizing System known as PARDS (Parts Digitizing System).

PARDS, which is managed by the Acquisition of Manufactured Parts (RAMP) Project Office. It is integral to the goal of faster and more reliable collection of part geometry data than is currently possible through manual methods.

Developed by Robotic Vision Systems, Inc. (RSVI), Hauppauge, NY, PARDS automatically acquires a complete surface map of any part placed within its work envelope. The system uses a structured laser light technique employing optical triangulation to gather true, volumetric 3-D data.

Highly focused planes of Class 1 laser light are projected from the PARDS machine vision sensors. These planes, when intersected by the workpiece, bend in exact conformance with the surface contour of that workpiece. As the thousands of laser light planes are scanned across the part by each sensor, a high-resolution solid-state camera is recording the spatial location of each plane. When data from all of the scanned planes is represented, a complete 3-D surface map of the part is available in the form of tens of thousands of discrete x, y, z data triplets.

In the case of parts with complex shapes, an individual sensor's view will often be blocked. To eliminate this problem, PARDS employs multiple vision sensors set at different viewing angles, enabling the system to see into otherwise obscured areas.

The system is comprised of two systems: the vision processor and the graphics workstation. The vision processor controls the four laser scanners, merges the data from them, thins redundant data and passes the surface coordinates to the graphics workstation.

The graphics workstation is a Sun workstation with CADDS 4X software. The software will automatically convert clouds of data points on the screen into CAD entities by identifying edges of planes, cylinders and conic sections. This geometric data will ultimately be used to create data after the addition of tolerance, material, features, inspection and process data.

After the end of project demonstration the system will be transferred to the Automated Manufacturing Research Facility (AMRF) at the National Institute of Standards & Technology (NIST). It will be used for parts to be put in PDES format. The system could also be used to scan completed parts during the quality control process. The system will finally be transferred to a Navy activity to assist in creation of product data from physical parts for the RAMP program.

PARDS related technology addresses needs far beyond the Navy's reverse engineering requirements. A similar RVSI system is digitizing aircraft honeycomb structures to facilitate automated repair. An even larger RVSI system, APOMS, developed for the U. S. Navy, precisely measures the 3-D contour of ship's propellers.

Interest in PARDS technology has been exhibited by industry as well. One potential commercial application is the 3-D mapping of autombile clay models. Presently digitized by coordinate measuring machines, PARDS offers a faster, non-contact solution with higher data density and greater flexibility.

The benefits of PARDS then, while significant to the RAMP program's goal of parts on demand, will likely be enjoyed throughout the military and commercial world.

For more information, contact:
Commander,
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Attn: Mr. James L. Mays
(PML5505MZA)
Washington, DC 20376
Telephone: (202) 697-4561

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Quick-Disconnect Valves for Modular Fluid Systems

Maintenance would be facilitated and loss of fluid minimized.

Maintainable (that is, inspectable and repairable) valves are being developed for use as interfaces between modules or other separable components in maintainable fluid systems. Although the new valves are being designed for temperature-regulating equipment aboard a space station, they could also be used with or without modifications in a variety of liquid and low-pressure-gas systems on Earth.

The valves (see Figure 1) are based on a cartridge-in-sleeve concept. The design minimizes the loss of liquid and the ingestion of gas or other contaminants during connection and disconnection or other maintenance activities. All of the seals and moving parts within the valves are maintainable.

Such features as two- or three-way switching, proportional valves, check or relief valves (see Figure 2), and some instruments can be integrated directly into valve cartridges. With the addition of probes, components larger than cartridges can be accommodated as though they fitted within the housings of the valves. In systems with damaged fluid lines, bypass lines instead of probes can be inserted into the housings.

This work was done by Charles Fluger, Rudolf Rexer, George J. Roebelen, and John B. Green, Jr., of United Technologies Corp. for **Marshall Space Flight Center.**
MFS-28262/TN

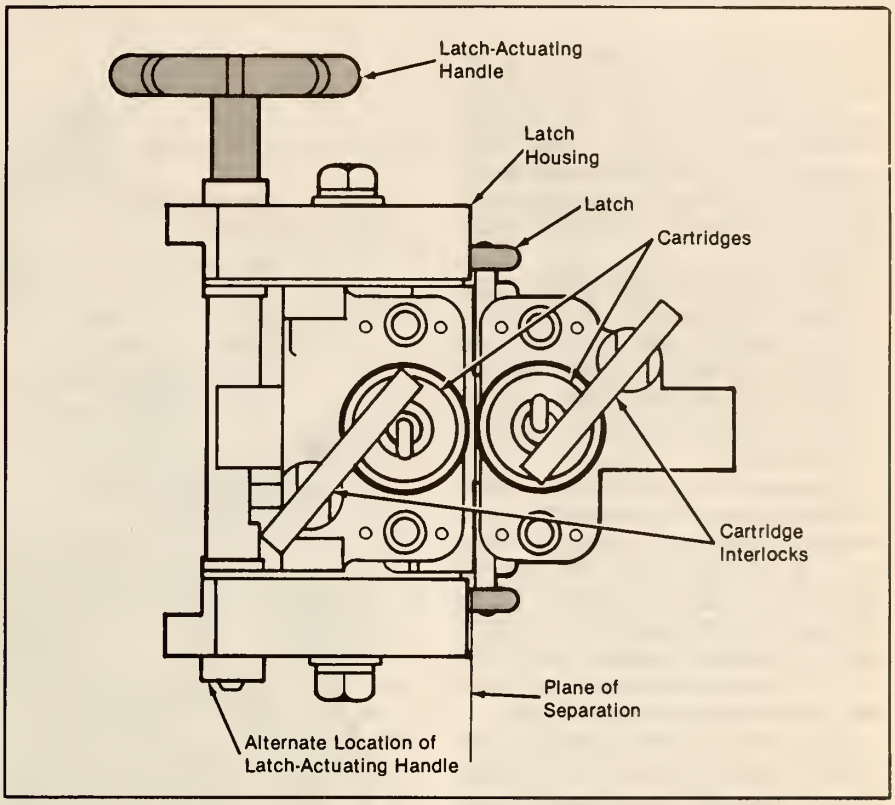


Figure 1. A **Pair of Valves** joins two plumbing subsystems, enabling them to be connected to or disconnected from each other and enabling either or both to be isolated upon disconnection.

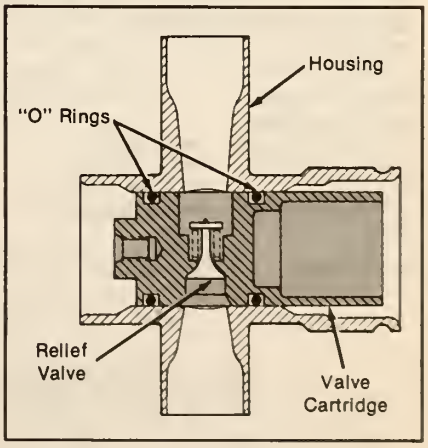


Figure 2. A **Relief Valve** is built into the cartridge of a maintainable valve; the cartridge can be removed for replacement or inspection.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Seal for Precooling a Turbopump

A diaphragm reduces misalignment.

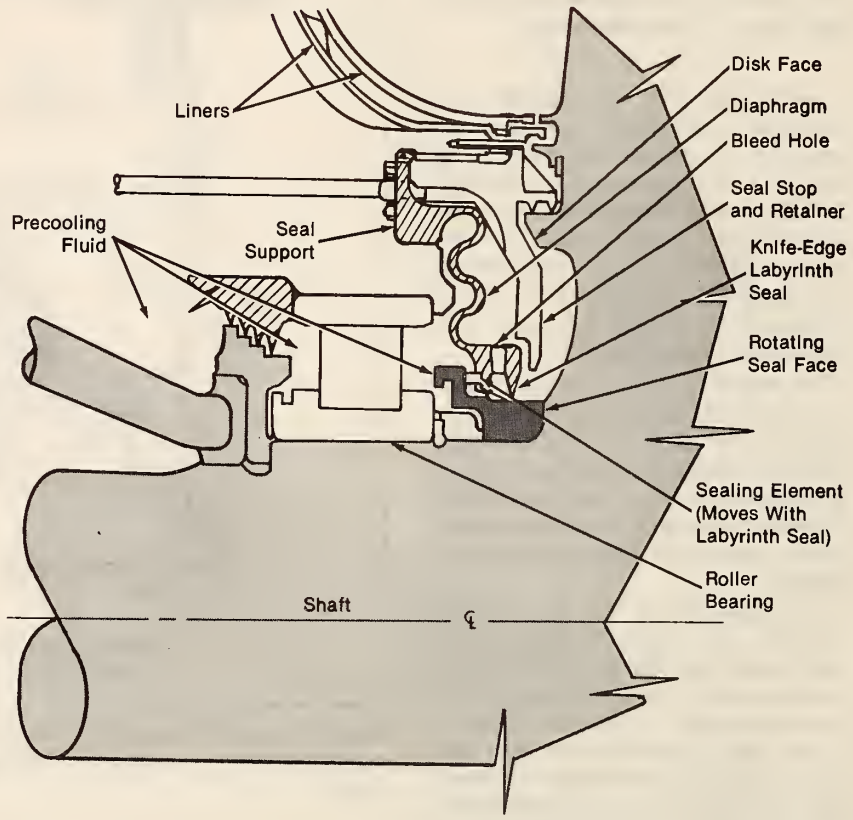
A rotary seal retains precooling fluid in the pump section of a cryogenic turbopump, preventing the fluid from entering the turbine section. The precooling fluid is needed to lower the temperatures of the pump parts, to reduce thermal shock and boiling when the cryogenic liquid enters the pump.

Before the turbopump is started, a sealing element rests against a highly-polished rotating seal face (see figure). When the turbopump is first assembled, the diaphragm holding the sealing element is bent to give the necessary sealing force against the seal face.

When the turbopump is started, the internal pressure of the liquid in the pump deflects the diaphragm axially until it seats on a seal stop. The portion of the fluid that leaks past the sealing element splits, part of it going through a bleed hole to cool the outer turbine elements and part of it leaking past a labyrinth seal to cool the liners and the rear face of the turbine disk.

This work was done by Samuel S. Owen and R. C. Mulready of United Technologies Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-28270/TN



Precooling Fluid is held in the pump section of a turbopump by a knife-edge labyrinth seal on a diaphragm.

George C. Marshall Space Flight Center
Technology Utilization Officer: Ismail Akbay
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Patent Counsel: Leon D. Wofford, Jr.
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FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Service Lives of Restored Bearings

Rebuilt units should last almost as long as new ones.

A report describes theoretical and experimental studies of the lifetimes of restored ball and cylindrical-roller bearings. The results of this and related studies have obvious implications for economy and safety in modern high-speed machinery, especially in the aircraft industry, where the inspection and rejection or replacing of bearings are now standard practice.

A used bearing is first inspected visually. If the raceways are damaged superficially (to a depth of less than 0.05 mm) and if they remain hard enough, the bearing is considered a candidate for restoration. Where necessary, the faces, bores, and outer diameters are ground and plated with either nickel or chromium to allow regrinding to the original outer dimensions. The raceways are then ground to a depth between 0.05 and 0.15 mm to remove all superficial damage and a portion of the subsurface fatigue damage.

The bearing is then fitted with new rolling elements of diameter equal to the original diameter plus twice the depth of regrinding. After inspection of the bearing separator for cracks, the bearing is reassembled. Although the raceways and rolling elements are slightly oversize, for engineering purposes the stress levels and geometrical relationships among the components are essentially identical to those of the original bearing.

The fatigue life of a rolling-element bearing is calculated by the Lundberg-Palmgren formula, which gives the relationships among the probability of survival, the number of stress cycles to failure, the stress, the stressed volume, and the depth of occurrence of the maximum orthogonal reversing shear stress. For new elements, the statistical dispersion in lifetimes is described by the Weibull distribution.

This theory of failures is applied to compare the lives of restored bearings to the lives of new ones. In a restored bearing, the location of the maximum orthogonal reversing shear stress is shifted deeper into the original material by the depth of regrinding. Thus, the stressed volume of a restored bearing includes a newly stressed portion plus an older portion that has a longer history of stress cycles. The probability of survival of the restored bearing is therefore estimated as the product of the probability of survival of the used material with that of the new material. A correction is made to account for the defective bearings discarded after inspection.

The final result of this theory is an equation for the probability that the restored bearing will survive an additional specified number of stress cycles as a function of the fraction of the stressed volume ground away during restoration and the number of stress cycles since manufacture at which it was restored. When representative parameters are inserted in this equation, it predicts that the lifetime during which there is a 10-percent probability that a restored bearing will fail ("10-percent life") ranges from 74 to 100 percent of the 10-percent life of a new bearing.

In the experiments, 250 bearings of three different types were restored. Of these, 30 of each type were chosen at random and tested under realistic operating conditions for 1,600 hours. None of the bearings suffered a failure related to regrinding. Two failures were due to defective rolling elements and were typical of those that occur in new bearings.

This work was done by Erwin V. Zaretsky of **Lewis Research Center**. *Further information may be found in NASA TM-88871 [N87-18820], [price code: A02] "Effects of Surface Removal on Rolling-Element Fatigue."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14704/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Coordinate Measuring at FERMILAB

Magnets (and lately, superconducting magnets) have always been at the heart of Fermilab's research efforts. The production of a magnet assembly by Fermilab's Technical Support Section (TSS) requires stacking steel laminations of precise sizes and shapes in order to create the desired magnetic field. These delicate operations must be performed in an environment of tight budgets and no established product line, leading to some inventive developments and useful techniques.

For instance, TSS embarked on a series of tests and evaluations which led to retrofitting the Section's coordinate measuring machines with a Sony CCD video camera mounted with a Unitron 1:6.5 zoom lens. After obtaining the desired accuracy with the CCD, TSS then addressed the problem of outputting the measurement data in a form more readily useful than a feature number keyed to a drawing. A plotter is used to draw a part the way it is supposed to be. The plotter then draws the measured part on top of the first drawing as measurement is taking place. In this way, a hardcopy provides a visual representation of the actual part shape and size in relation to the specifications.

FOR ADDITIONAL INFORMATION: Office of Research and Technology Applications, Fermi National Accelerator Laboratory, P.O. Box 500, MS 208, Batavia, IL 60510; (312) 840-3333. Refer to FAA-219/TN.

Oak Ridge National Laboratories

Soft-Thresholding Image Analysis

Radiographic inspection of manufactured parts is a material- and labor-intensive task. As such, it is a good candidate for automation: film can be replaced with X-ray-sensitive cameras, and human film readers with image processing/analysis software. One of the crucial problems in automated radiographic inspection is defining the regions of interest of the radiograph, usually under severe time constraints. It is the task of the image-processing software to mimic the behavior of human film readers and select these regions. Software for this task has been developed at the Oak Ridge Y-12 Plant.

The Soft-Thresholding Image Analysis (STIA) computational algorithm was developed to rapidly detect anomalous regions in digital (or digitized) radiographs. It is implemented mostly on an image processor, with a small portion of the computation performed by the host computer. STIA generates a computerized image, or "mask," out of individual pixels that have been evaluated in terms of their "gray level," or brightness. Requiring only 12 s to generate a region-of-interest mask, STIA is sufficiently fast for use in nearly real-time inspection applications.

In contrast to "hard-thresholding" techniques, STIA is insensitive to the number of artifacts in an image and is very sensitive to defects whose gray levels are close to each other and/or the background. Hard thresholding requires an a priori knowledge of the number of regions of interest. In addition, it requires that the gray levels in the defects be reasonably well separated in value so that breakpoints may be unambiguously set. STIA does not require a priori knowledge of the shapes or locations of artifacts in an image. Instead, the likelihood that a pixel is part of the foreground is determined from the characteristics of the distribution of pixel gray levels. Pixels are then assigned to the foreground or background based on a "coin toss" designed to be consistent with the likelihood function. Thus the algorithm is correct on average.

Figure 1 shows a digital radiograph of five flat-bottom holes drilled into a metal plate. A center hole is surrounded by four smaller holes at the corners of a rectangle. The hole at the lower left-hand corner is barely visible and could be easily overlooked by a human film reader. The figure is a positive image in which the darker shades indicate mass defect. Figure 2 shows the region-of-interest mask generated by STIA. All five holes are indicated.

STIA was developed without regard to the source of the digital images. It is only necessary that the gray levels of the background pixels be normally distributed. Thus it is expected that the algorithm will find application in most radiographic environments, including industrial and medical scanning. It is also likely that the algorithm can find use in military applications such as surveillance and target-location systems.

Fig. 1. Digital radiograph showing five holes.

Fig. 2. Region-of-interest mask generated by soft-thresholding image analysis.

Additional information:

Office of Technology Applications
Martin Marietta Energy Systems, Inc.
P.O. Box 2008
Oak Ridge, TN 37831-6257

Telephone: (615) 574-4192; FTS 624-4192

Z. W. Bell, *An Image Segmentation Algorithm for Nonfilm Radiography,* Y/DW-653, Oak Ridge Y-12 Plant (August 1986), and pp. 773-79 in *Review of Progress in Quantitative Nondestructive Evaluation 6A,* ed. Donald O. Thompson and Dale E. Chimenti, Plenum Press, New York (1987).

Z. W. Bell, *A Bayesian/Monte Carlo Segmentation Method for Images Dominated by Gaussian Noise,* Y/DW-713, Oak Ridge Y-12 Plant (February 1987).

Z. W. Bell, *Evaluation of Thresholding Heuristics Useful for Automated Filmless Radiography,* Y/DW-718, Oak Ridge Y-12 Plant (July 31, 1987).

Materials

0389 Improved Stability of Al-Fe-Mo Rapidly-Solidified Alloys

0390 High Temperature Materials Laboratory

0391 Nickel-Iron Aluminides for Advanced Coal Conversion Systems (Licensing Opportunity)

0392 Millimeter Size Single Crystals for Superconducting $YBa_2Cu_3O_x$

0393 Corrosion Fatigue of Amorphous Fe-Cr-B-Si Alloys

0394 Corrosion-Wear of M50 Bearing Steel

0395 Bulk Asbestos Standard Available for Inspectors

0396 Fibers and Composites Derived from Silsesquioxanes—Shrinkage and voids are suppressed. (Licensing Opportunity)

0397 Improved Consolidation of Silicon Carbide—Careful processing increases strength.

0398 X-Ray-Scattering Measurements of Strain in PEEK—Internal stress is relieved by heating above the glass-transition temperature.

0399 Strategic Materials for Superalloys—U.S. resources and reserves and possible substitutions are assessed

Testing & Instrumentation

0400 Development of an Automated X-Ray Gauge for Nondestructive Quantitative Analysis

0401 Static and Dynamic Metal-Metal Friction at Plastic Stress Levels

0402 X-Ray Methods for Analyzing Rough Wear Surfaces

Other Items of Interest

0353 Stacked Metal Silicide/Silicon Far-Infrared Detectors—The long-wavelength limit would be extended. (Licensing Opportunity)

0361 Economics, Efficiency of Insulation Without Chlorofluorocarbons

0364 Composite Embedded Fiber Optic Sensor for Measurement of Structural Vibrations

0417 Temperature Measurement from 1300K to 6000K (Licensing Opportunity)

0418 Gas-Jet Cooling Would Improve Czochralski Process—The diameter of the growing crystal would be more stable and controllable. (Licensing Opportunity)

Improved Stability of Al-Fe-Mo Rapidly-Solidified Alloys

Studies supported by the Air Force Office of Scientific Research at the University of Illinois have shown that the addition of small amounts of silicon, up to 1.0 weight percent, result in a significant improvement in the resistance of the rapidly solidified A1-8Fe-2Mo alloy to coarsening upon exposure to elevated temperatures. Al-8Fe-2Mo alloys containing 0, 0.5, or 1.0 percent silicon were produced as rapidly solidified ribbon by casting pre-alloyed material onto a rotating mild steel wheel. The ribbon material was subsequently annealed for periods up to 100 hours at 840 F (450 C) and examined using transmission electron microscopy and X-ray diffraction to determine the types of precipitates that formed during the annealing treatment and the effect of annealing time on the precipitate size. It was found that silicon additions resulted in the development of a uniform dispersion of an Al12(Fe,Mo)3Si phase which was much more resistant to coarsening than the mixture of Al-Mo-Fe, Al-Fe, and Al-Mo phases found in Si-free alloys. It was suggested that addition of silicon to Al-Fe-Mo alloys may result in appreciable improvements in their serviceability at elevated temperatures.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.
NTIS order number: AD-A187953/NAC
Price code: A05

Department of Energy

Technology Application

Oak Ridge National Laboratories

High Temperature Materials Laboratory

The High Temperature Materials Laboratory (HTML) is a $19 million facility that serves as the focal point for high-temperature ceramics research at the Oak Ridge National Laboratory (ORNL). It is also a major user facility, providing members of the industrial and university research communities access to the extensive array of special research equipment needed to characterize the microstructure and microchemistry of materials and to investigate the effect of these parameters on the physical and mechanical properties of the materials. User research equipment is divided among four User Centers: Materials Analysis, High Temperature X-ray Diffraction, Physical Properties, and Mechanical Properties. This brochure provide brief descriptions of each of the major pieces of research equipment in the User Centers. Hands-on operation of this equipment by qualified users is encouraged. A User Center staff is available with special responsibility of maintaining the User Center equipment any for interacting with users. Both proprietary and nonproprietary research may be performed by users in the HTML. No charge is made for access to the research equipment for nonproprietary research. Proprietary research, on the other hand, is done on a full cost recovery basis.

FOR ADDITIONAL INFORMATION: Contact, V.J. Tennery, HTML Director, Bldg. 4515, MS 062, Oak Ridge National Laboratory, PO Box X, Oak Ridge, TN 37831; (615) 574-5124.

Technology Application

Oak Ridge National Laboratories

Nickel-Iron Aluminides for Advanced Coal Conversion Systems

Current structural alloys, including austenitic stainless steels and nickel-based superalloys, do not have an adequate combination of strength, ductility, and corrosion resistance for structural use in the hostile environment of a coal-conversion system. ORNL researchers, working under the sponsorship of DOE's Fossil Energy Materials Program, have developed a nickel-iron aluminide superalloy (Ni_3Al + Fe) that is suitable for structural use in advanced coal-conversion systems. The needed qualities of strength, ductility, weldability, and corrosion resistance are combined in this new superalloy.

Three tasks were involved in the development of nickel-iron aluminides. First, the mechanical and metallurgical properties of nickel-iron aluminides were improved by controlling alloy compositions; both micro- and macro-alloying processes were used to improve the alloy's properties. Second, the study of corrosion behavior of nickel-iron aluminides in sulfidizing environments provided data for improving corrosion resistance specifically for coal-conversion applications. Third, electron-beam and gas-tungsten arc welding processes for selected aluminides were studied and improved.

To accomplish the first task, the researchers systematically studied the alloying effects of a variety of additives [Cr, Fe, Zr(Hf), Ti, Mo, and B]

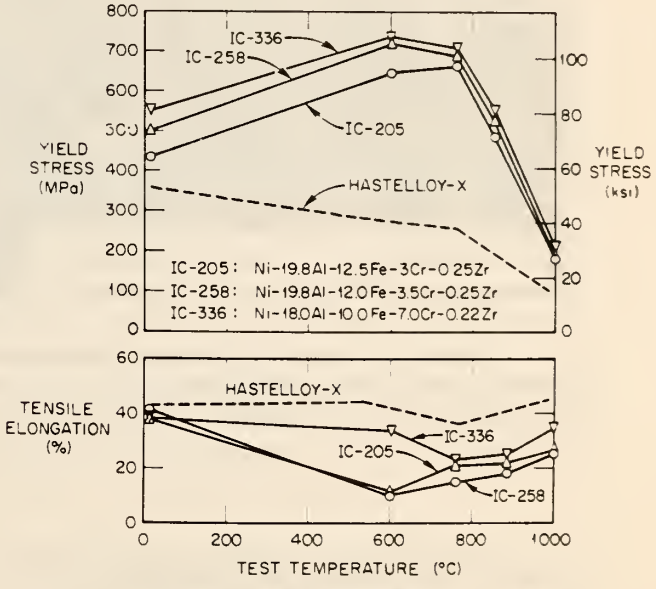

Fig. 1. Comparison of tensile properties of nickel-iron aluminides (IC-205, IC-258, and IC-336) with the commercial alloy Hastelloy-X. The aluminides are much stronger, particularly at elevated temperatures. The ductility of the aluminides is comparable to that of Hastelloy-X at room temperature; ductility is lower, but still adequate, at elevated temperatures.

Fig. 2. Transverse metallographic section of an electron-beam weld made in a nickel-iron aluminide alloy. Notably absent are both cracking and porosity. Weldability of the aluminides depends on surface condition, welding parameters, and minor alloy additions.

on nickel-iron aluminides; then they determined the optimum composition. The final alloys have a good combination of strength, ductility, and fabricability and are significantly stronger than commercial alloys (Fig. 1). A screening test was used to accomplish the second task: samples were exposed to the decomposition products of $CaSO_4$ to evaluate sulfidation resistance of samples containing chromium, silicon, or both. Third, samples of nickel-iron aluminides were successfully welded (Fig. 2).

C. T. Liu et al., *Initial Development of Nickel and Nickel-Iron Aluminides for Structural Uses,* ORNL-6067, Oak Ridge National Laboratory (August 1984).

C. T. Liu et al., *Development of Nickel-Iron Aluminides,* ORNL-6412, Oak Ridge National Laboratory (September 1987).

Additional information:

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P.O. Box 2008
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Millimeter Size Single Crystals for Superconducting $YBa_2Cu_3O_x$

The discovery of superconducting metal-oxide ceramics signals potential major advances in transportation, electronics, power generation and transmission, integrated circuits and computers. However, many potential applications require that the material first be made into wires, films, or thin sheets. Ames Laboratory researchers have developed a process for growing single crystals of $YBa_2Cu_3O_x$ superconducting material, from which such useful shapes can be made.

The Ames Laboratory-developed procedure is the first process for making single crystals up to 1 millimeter in size. The procedure is simple, efficient, and delivers high yields. First, copper oxide, yttrium oxide, and barium carbonate powders are mixed with an excess of copper oxide and heated to form a melt flux. The mixture is rapidly cooled to room temperature and then reheated. As the flux is held at a temperature below the melting point of $YBa_2Cu_3O_x$, single crystals form.

An advantage of this method is that it provides the optimum conditions for ensuring the proper oxygen content. Structural studies have shown that the number and arrangement of oxygen atoms is a key determinant of the oxide superconducting properties. Since excess barium oxide (carbonate) is not used in the process, the single crystals are quite stable in moist air and do not lose their superconducting properties over a period of time.

Single crystals allow a material to achieve the optimum superconducting properties. For example, single crystals can be properly oriented in direction, which maximizes such properties as critical current density. A material composed of large crystals has fewer grain boundaries; grain boundaries in polycrystalline $YBa_2Cu_3O_x$ have a deleterious effect on the superconducting properties.

This procedure shows strong potential for becoming the first step in successfully growing even larger single crystals, which are needed for many of the commercial applications using superconductors.

Literature: M. A. Damento, K. A. Gschneidner, Jr., and R. W. McCallum, "Preparation of Single Crystals of Superconducting $YBa_2Cu_3O_{7-x}$ from CuO Melts," *Applied Physics Letters*, **51**(9), 31 August, 1987, p. 690,691.

Patent/License Status: A patent application has been filed.

Potential Applications/Spinoffs: Electronics, integrated circuits, transportation, power generation and transmission.

For More Information on this Technology: Contact Daniel E. Williams, Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, Iowa 50011 (515)294-2635.

AL 88-01

U.S. Navy Fact Sheet

Corrosion Fatigue of Amorphous Fe-Cr-B-Si Alloys

The corrosion fatigue of amorphous Fe75-xCrxB15Si10 wire has been studied at the Naval Surface Weapons Center with a possible application in cables. 0.005 in. diameter wires of amorphous alloy containing 5, 8, and 11 a.o Cr were corrosion tested and fatigue tested in 3.5 percent NaCl solution and in 1.0N H2SO4. Polarization measurements revealed that only the 5 a/o Cr alloy exhibited active/passive behavior and only in 3.5 percent NaCl. All other alloys showed complete passivity in both solut ions. Pitting potentials varied only slightly with alloy composition in the two solutions. Compared to values obtained in air, the corrosion fatigue life was reduced in both solutions with the greater reduction occurring in 1.0N H2SO4. However, an unusual phenomenon was observed: if a fatigue test was stopped after about a third of the time to failure, the specimen was then allowed to remain in the test solution with no cyclic load for a comparable period of time (15 minutes), and the fatigue test was subsequently resumed, then that specimen exhibited fatigue behavior of virgin material. This unusual result was attributed to the strong passivation behavior of these alloys which would "heal" cracks in the passive film that otherwise would ultimately lead to fatigue cracking.

Papers are solicited which address development and application issues for the broad range of structural materials including ceramics, metal matrix composites, organic matrix composites, modern metallic alloys, polymers, and hybrids. Experimental, computer simulation and theoretical papers are solicited which address one of the following or associated topics:

Constitutive Relations
Failure Modes, Life Prediction, Reliability Methods
Mechanics of Processing
Test and Evaluation of Engineered Materials
Structural Theories for Applications

Authors should submit extended abstracts of approximately one thousand words with associated figures. Submissions should be sent by December 16, 1988. Notification of acceptance will be madeprior to January 16, 1989. Abstracts will be published in proceedings which will be distributed at the Symposium.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.
NTIS order number: AD-A189106/NAC
Price Code: A03

U.S. Navy Fact Sheet

Corrosion-Wear of M50 Bearing Steel

Corrosion-wear processes under rolling-sliding motion have been investigated at IIT Research Institute in studies conducted for the Naval Air Development Center. M50 bearing-quality steels were evaluated by polarization techniques under rolling and sliding motion in a dynamic corrosion-wear electrochemical cell that contained inhibitors and lubricants in a 100 ppm NaCl solution. Under pure rolling conditions, wear was significant in removing the passive film as indicated by an increase in the corrosion current and a decrease in the corrosion potential. Increasing the load and/or the introduction of a few percent sliding, generated more severe wear conditions as shown by the polarization measurements. A statistical analysis of the results revealed that 500 ppm Na2Cr2O7 was most effective in reducing corrosion-wear. Of the variables studied, sodium dichromate followed by the extent of sliding employed in the tests had the most significant effect on the corrosion potential, while sodium dichromate followed by lubricant and contact stress had the most significant effect on corrosion current density. A combination inhibitor that contained 500 ppm NaNO2 and 500 ppm Na2Cr2O7 had a dramatic effect in reducing corrosion-wear in the absence of lubricating oil.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: AD-A189603/NAC

Price code: A06

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Bulk Asbestos Standard Available for Inspectors

A set of asbestos standard reference materials (SRMs) is available for laboratories involved in the National Voluntary Laboratory Accreditation Program (NVLAP) on Bulk Asbestos and for others concerned with asbestos abatement projects. The SRMs are typical of asbestos types found in bulk samples during routine inspections of building materials. The set consists of three common mine-grade asbestos materials and one synthetic glass fiber sample. The asbestos types are chrysotile, grunerite (amosite, and riebeckite (crociodolite). The optical properties of the materials have been characterized for use as a primary calibration standard for identifying asbestos types in building materials. The glass fiber sample does not contain asbestos, and can be used to check procedures and equipment for contamination that would affect the accuracy and limits of detection of asbestos analysis.

FOR ADDITIONAL INFORMATION: SRM 1866, Bulk Asbestos-Common, is available for $375 from the Office of Standard Reference Materials, B311 Chemistry Bldg, NIST, Gaithersburg, Md. 20899; telephone: 301/975-OSRM (6776).

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

Fibers and Composites Derived From Silsesquioxanes

Shrinkage and voids are suppressed.

A method has been developed for the production of narrow ceramic fibers by melt spinning and for the production of ceramic composite materials by coating or infiltrating preforms or felts of such fibers. Silsesquioxanes having the general formula RSiO (where R is methyl, ethyl, propyl, vinyl, phenyl, or allyl) have been used to produce ceramic SiC powders and as components of resin sols for the impregnation of mats of fibers to form ceramic/matrix composites. Heretofore, the fabrication of composites by impregnation with solutions has required the removal of solvents, with the possibility of subsequent formation of voids and large shrinkages if removal is initially incomplete.

Ceramic fibers and matrices have also been fabricated from polysilane, polycarbosilane, and polysilazane precursors. However, syntheses with many steps are necessary to obtain these polymers, and the stoichiometric ratios of the resulting ceramics are difficult to control. By comparison, the silsesquioxanes are easily synthesized; some are produced commercially for use as additives in paints.

In the new method, silsesquioxane powders are blended to control the ratio of carbon to silicon. The blended powders are melted, and the excess silanol groups condense with the evolution of water. When the melt attains a suitable viscosity, it can be extruded into fibers through a die or drawn into fibers from the melt at a uniform rate. The fibers are then cured and heat treated.

The process for making composites begins with the winding of the fiber on a mandrel and the coating of the wound fiber with the silsesquioxane melt. After cooling, the fiber "prepreg" is cut into plies and stacked in a metal mold. The mold is inserted into a cold press, heated to a set temperature, and held under contact pressure during a specified time. Then the mold is heated to a new set temperature, a new specified pressure is applied, and the new pressure and temperature are maintained during a specified time. The laminate is then allowed to cool to room temperature before it is removed from the mold. The laminate is then cured and heat treated. The silsesquioxane melt can also be used to infiltrate a fiber preform.

The new method enables the easy fabrication of thermally stable fibers from inexpensive silsesquioxane precursors. Furthermore, the rheological properties of the melt and the composition of the fired ceramic can be controlled through the selection of the ratio of carbon to silicon in the starting polymer. Finally, the impregnation of fibers and preforms without solvent minimizes both the shrinkage and the formation of voids that result from the volatilization of trapped solvent.

This work was done by Frances I. Hurwitz, Lizbeth H. Hyatt, Lisa A. D'Amore, and Joy P. Gorecki of **Lewis Research Center.** *Further information may be found in NASA TM-89893 [N87-25432/NSP], [price code: A02] "Silsesquioxanes as Precursors to Ceramic Composites."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center. Refer to EW-14566/TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

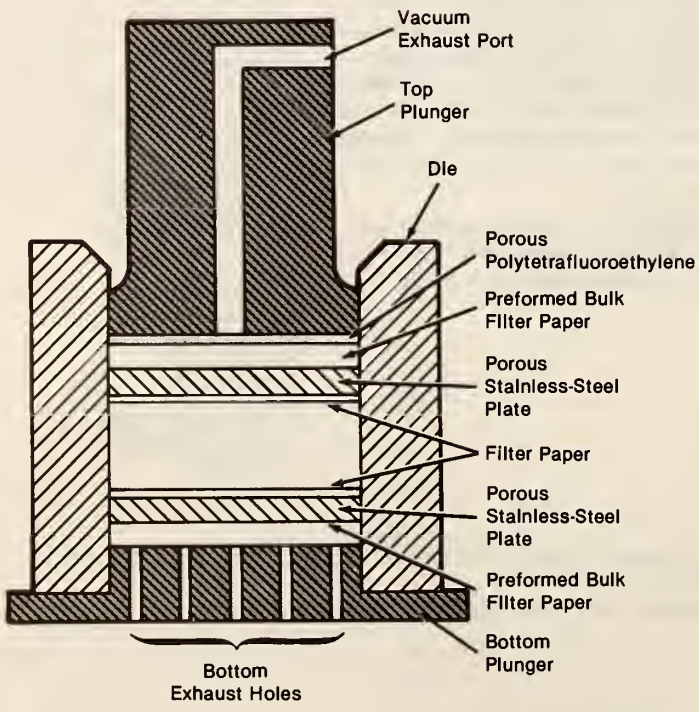
Improved Consolidation of Silicon Carbide

Careful processing increases strength.

Silicon carbide (SiC) and silicon nitride (Si_3N_4) are currently being evaluated as replacements for strategic metals in applications ranging from heat engines to industrial heat exchangers. The primary disadvantage of these materials is the inability to control fracture-generating flaws that lead to failures of components.

Agglomerates in the starting powders control the flexural strengths of sintered SiC test specimens. The dependence of mechanical properties upon these flaws obscures the effects of such important processing variables as compositions, sintering times, and sintering temperatures on the properties of sintered SiC. Slurry pressing was developed as a technique to avoid or eliminate agglomerates as sources of critical flaws.

The slurry-pressing die is shown schematically in the figure. The die works on a push-pull principle to draw the liquid out of the slurry. Liquid is pushed out through exhaust holes in the bottom plunger during pressing. Liquid is pulled out from the slurry through an exhaust hole in the top plunger attached to a vacuum pump. The other components of the die include filter paper to trap the powder, porous stainless-steel plates for uniform expulsion of liquid and forming, preformed bulk filter paper that swells during pressing to prevent leakage around the plunger, and an additional seal of porous polytetrafluoroethylene.



The **Slurry-Pressing Die** presses and draws the liquid out of the slurry as it presses the slurry into the desired shape.

Colloidal techniques were used to improve the dispersion and suspension of SiC in water. In combination with slurry pressing, these techniques resulted in an increase in the strength of sintered SiC by 87 percent over that of SiC sintered after dry pressing. The improvement was due to reduced porosity (as shown by image analysis) and was reflected in improved densities of "green" (unheated) and sintered specimens. Smaller sizes of pores and reduced sizes of critical flaws also contributed to the increase in strength.

Thus, with careful colloidal control of the slurry, aqueous slurry pressing provides a means of consolidating ceramic powders to form simple to moderately complex shapes. The technique should be useful for making parts from particulate-, transformation-, and whisker-toughened ceramics as well as monolithic ceramics. It should also provide an avenue for the study of the many other variables that contribute to the reliability of current structural ceramics.

This work was done by Marc R. Freedman of **Lewis Research Center** *and Michael L. Millard of General Electric Co. Further information may be found in NASA TM-87243 [N86-24836/NSP], [price code: A02] "Improved Consolidation of Silicon Carbide."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

LEW-14681/TN.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

X-Ray-Scattering Measurements of Strain in PEEK

Internal stress is relieved by heating above the glass-transition temperature.

A report describes wide-angle x-ray scattering and differential scanning calorimetry of specimens of poly(etheretherketone) (PEEK) that have undergone various thermal treatments. Wide-angle x-ray scattering is particularly useful in determining distances between atoms, crystallinity, and such related microstructurally generated phenomena as thermal expansion and strain. The calorimetric measurements aid the interpretation of scattering measurements by enabling correlation with thermal effects.

Two materials were studied: (1) a low-molecular-weight PEEK powder synthesized in the laboratory and (2) high-molecular-weight commercial PEEK pellets. These materials were hot-pressed at 350 and 370 °C, respectively, then quenched to make thin amorphous (noncrystalline) films. The films were cold-crystallized at 176 °C for 24 hours, then annealed in flowing air at temperatures ranging from 230 to 319 °C. After annealing, the samples were cooled quickly to room temperature.

The wide-angle x-ray measurements were taken before and after the heat treatments. A diffractometer with copper-K_α radiation filtered through nickel was used to obtain scattering patterns in the reflection mode. The specimens were spun in the plane of the film during these measurements to average out the effects of orientations.

The scattering data suggest that thermal stresses are frozen into the material upon cooling: internal stresses apparently develop in the amorphous phase, causing the observed shifts in the amorphous-phase scattering peaks to smaller scattering angles, corresponding to larger spaces between molecular units. The low-molecular-weight material was found to be more susceptible to the creation of internal stresses.

To demonstrate that the observed shifts were indeed due to internal stresses in the amorphous phase, several films were subjected to differential scanning calorimetry before and after a treatment in which they were heated to just above the glass-transition temperature held for 5 minutes, then cooled slowly to room temperature. A stress-relief endotherm was observed in the untreated samples at the glass-transition temperature but not in the treated samples. In the treated samples, the x-ray-scattering measurements show that the molecules have relaxed to the equilibrium volume configuration.

This work was done by Peggy Cebe, Lynn E. Lowry, Shirley Y. Chung, Andre H. Yavrouian, and Amitava Gupta of Caltech for **NASA's Jet Propulsion Laboratory**. *"Wide Angle X-Ray Scattering of Strain in the Amorphous Phase of Poly(etheretherketone),"*

NPO-17097/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration

Strategic Materials for Superalloys

U.S. resources and reserves and possible substitutions are assessed.

A report discusses the status of strategic materials for superalloys in the United States. The report reviews trends in the development of superalloys, defines "strategic" materials, summarizes the state of U.S. resources and reserves, and discusses sources and availability of supplies. It reviews the results of the Conservation of Strategic Aerospace Materials (COSAM) program.

The report assigns the elemental constituents of superalloys to the following three groups according to increasing strategic value:

1. Aluminum, copper, molybdenum, magnesium, and iron;
2. Vanadium, rhenium, titanium, tungsten, silver, nickel, and gold; and
3. Tantalum, chromium, platinum, niobium, manganese, and cobalt.

Superalloys are the major materials of construction for high-temperature gas-turbine engines for both military and commercial aircraft. However, for the superalloy industry to thrive in the United States, there must be a readily available supply of the alloying ingredients. In the ideal situation, mining companies in the United States would be the primary suppliers to the alloy producers. Unfortunately, the United States has no ample reserves and resources of some of the ingredients and over the years has become increasingly dependent on foreign sources.

As a result of the COSAM program, however, technology was established for the substitution of other ingredients for strategic materials in nickel-base superalloys. This is especially true for cobalt; the physical metallurgy of low- and zero-cobalt alloys was characterized in terms of composition, microstructure, heat treating, and thermomechanical processing. Similar studies were done for tantalum and, less extensively, for niobium. In continuing research, iron and nickel aluminides, metal-matrix composites, and intermetallic-matrix composites have shown promise as potential replacements for superalloys containing cobalt, tantalum, niobium, and chromium.

This work was done by Joseph R. Stephens of **Lewis Research Center**. *Further information may be found in NASA TM-89866 [N87-21077], [price code: A03] "Superalloy Resources — Supply and Availability."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14665/TN.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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Department of Energy

Technology Application

Sandia National Laboratory

Development of an Automated X-Ray Gauge for Nondestructive Quantitative Analysis

An x-ray gauging system has been developed for nondestructive quantitative analysis. The automated device utilizes the transmission of low-energy x-rays through a material in order to measure the areal density of the material. If the material density is known, the x-ray gauge serves as a non-contacting thickness gauge, typically for micrometer-range dimensions. On the other hand, if the material thickness is know, x-ray gauging measurements yield the volume density of the material, so that quantitative chemical analysis may be achieved. Under some conditions, one material may be examined in the presence of another, making the gauge useful for examination of a thin coating on a substrate or of an element dispersed in a host matrix. Using digital rather than analog conversion techniques, measurement precision of 9.1% and accuracy near 0.5% have been achieved, with analytical correction for x-ray detection losses. The accuracy of the instrument has been demonstrated by comparison with chemical quantitative analysis techniques. Compared to chemical techniques, the x-ray gauge is faster, lower cost and nondestructive while maintaining measurement accuracy. In addition, accuracy has been demonstrated in analysis for elements for which calibration standards were not available. This feature offers a significant advantage over chemical analysis methods which require a known calibration standard for each element to be measured. The x-ray gauge thus provides a technique for rapid, accurate and automated nondestructive quantitative analysis of materials with minimal operator attention and sample handling.

FOR ADDITIONAL INFORMATION: A copy of this report is available from NTIS, Springfield, VA 22161; (703) 487-4700.

NTIS order number: DE88-008633/NAC

Price code: A04

To discuss this effort further, contact William Drotning, Sandia National Lab., Albuquerque, NM 87185.

Sandia National Laboratory

Static and Dynamic Metal-Metal Friction at Plastic Stress Levels

A new test technique has been developed for the study of adhesive metal/metal friction at high sliding rates and plastic stress levels. The test specimen consists of two pieces: a thick walled metal tube and a tapered metal rod. The rod is pulled through the tube in a servohydraulic load frame at rates up to ~10 to the 4th exponential power mm/sec. The level of plasticity experienced by the tube can be varied by changing the dimensions of the tapered rod. Large strain elastoplastic finite element simulations were used in the development of the test specimen and fixture. Both the quasistatic code JAC and the dynamic wave propagation code PRONTO were successfully utilized. An initial series of three tests has been performed using annealed OFHC copper tubes and cold worked 316 stainless steel rods to evaluate the specimen and fixture design. Two tests were performed at velocities of 1.67 mm/sec.: one using unlubricated, polished pieces and one using parts coated with a Molybdenum Disulfide spray lubricant. Lubrication resulted in approximately a factor of two reduction of load. The third test was performed unlubricated at a displacement rate of 7.44x10 to the 3rd exponential power mm/sec, using a high rate servohydraulic load frame. This test yielded a maximum load one half that found in the unlubricated static test, indicating a rate dependence of the plastic friction coefficient. The finite element model of the test has been compared with the experimental force displacement histories to infer the efffective friction coefficient for the various test conditions. The results suggest that the unlubricated, static test yields a value u=0.4 while both the lubricated, static test and the unlubricated, dynamic test result in u=0.2. These results are consistent with those of previous workers and with features observed on the wear surfaces using scanning electron microscopy. This new test promises to be a useful tool for the study of metal-metal frictional interaction in the presence of gross plastic deformation.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: DE88-011281/NAC

Price Code: A03

To discuss this research further, contact R. J. Bourcier, Mechanical Metallurgy Division 1832, Sandia National Laboratories, Albuquerque, NM 87185

Oak Ridge National Laboratories

X-Ray Methods for Analyzing Rough Wear Surfaces

A variety of research tools has been applied to the study of tribology, the science and technology of friction, lubrication, and wear. One area of fundamental tribological interest is the microstructural characterization of wear surfaces. Characterization techniques have included optical and electron microscopy, surface chemical microanalysis, and microindentation studies. One particularly challenging area of surface characterization has been the determination of residual stress states and crystallography of worn surfaces. For example, understanding the cause-and-effect relationships between the microstructures of ceramics and their wear resistance is a key element in the development of new high-temperature materials for such applications as low heat rejection engines. Future research into the effects of sliding wear and abrasion processes on the condition of the subsurface microstructures of candidate materials will benefit from the new X-ray methods developed under subcontract to ORNL.

Traditional X-ray methods for residual strain determinations have not been successfully applied to rough, heavily grooved wear surfaces because the supporting diffraction theory was developed

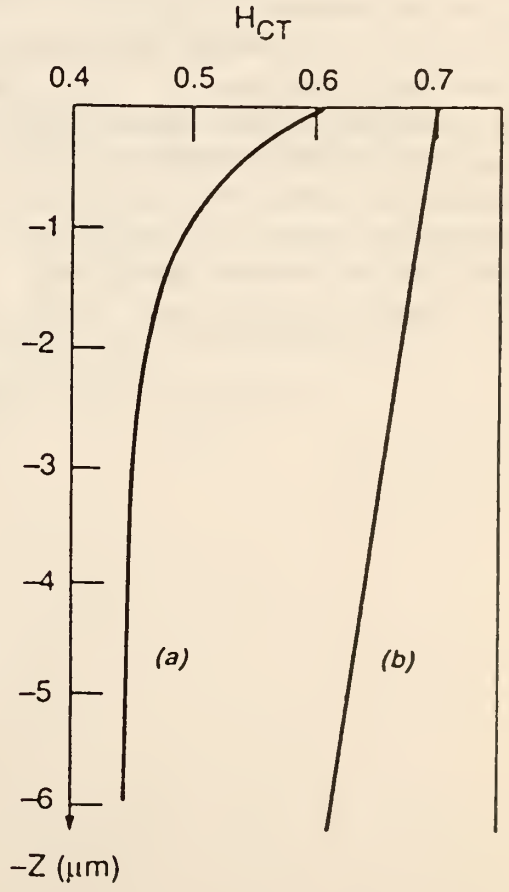

Fig. 1. Volume fraction of both cubic and tetragonal zirconia phases (H_{CT}) in the microstructure as a function of depth (Z) below (a) polished and (b) worn surfaces.

for atomically flat surfaces only. At Virginia Polytechnic Institute, recent work sponsored by the Energy Conversion and Utilization Technologies (ECUT) Tribology Project has resulted in the development of X-ray methods for use in studies of rough wear surfaces. These new methods were applied first to wear surfaces of fully stabilized and partially stabilized zirconia.

Wear tracks were generated by sliding a hemispherically tipped, unlubricated zirconia pin on a polished zirconia disk. Using symmetrical and asymmetrical diffraction optics, the researchers then determined the volume fractions of high-temperature phases as a function of depth below both polished and worn surfaces (Fig. 1). From these results, they determined that sliding-induced deformation produced crystallographic transformations in the subsurface microstructure of the zirconia.

These new X-ray techniques have also made near-surface strain gradient determinations possible for wear surfaces. Initial results on fully stabilized zirconia specimens show high strain gradients (80% per micrometer depth) below ground surfaces that exhibited deeper damage zones (about 3 μm deep). The maximum strain at the surface was slightly higher for the polished surface (4.5%) than for the ground surface (3.7%).

For a copy of the report, contact

Office of Technology Applications
Martin Marietta Energy Systems, Inc.
P.O. Box 2008
Oak Ridge, TN 37831-6257
Telephone: (615) 574-4192; FTS 624-4192

P. J. Blau, *Development of X-ray Methods for Analyzing Rough Wear Surfaces: Technical Summary of Subcontract # 19B07733B,* ORNL/TM-10710, Oak Ridge National Laboratory (1988).

For more information about the research, contact

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Blacksburg, VA 24061

Medicine & Biology

0403 AIDS Reference Service

0404 Enzyme for Materials Synthesis Altered Through Manipulation of its Gene

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0411 Extending the Shelf Life of Blood Platelets—Storing the platelet suspension in a thin layer allows the exchange of metabolic gases. (Licensing Opportunity)

Other Items of Interest

0337 New Virus Mix Kills Insects in Raisins (Licensing Opportunity)

0380 Concentric Micronebulizer for Direct Sample Insertion

AIDS Reference Service

AIDSLINE, a new data base containing over 13,000 references to scientific articles about AIDS, is now available to the medical research community through a joint effort of the National Library of Medicine (NLM) and the NIH Office of AIDS Research. AIDSLINE joins the existing family of data bases widely available through the NLM's online network.

The references in AIDSLINE cover the clinical and research aspects of the disease, epidemiology, and health policy issues. Many of the records include an abstract in English. The articles cover the period 1980 to the present, and the data base is updated twice each month with the addition of 200 to 300 records.

"It's not often that the Library adds a new data base to its MEDLARS family of 25 or so online files," says Kent Smith, NLM's deputy director. "Concern about AIDS, however, as expressed by the Congress and society at large, justified our creating AIDSLINE and making it available."

Initially, AIDSLINE references are being drawn from NLM's MEDLINE data base. In early 1989 the new data base will be expanded with AIDS references from two other NLM online files, CANCERLIT and the Health Planning and Administration data base.

Health professionals who wish to access AIDSLINE may join the NLM network by requesting a user code. To make online searching easier and more efficient, NLM offers GRATEFUL MED, microcomputer-based software that provides a user-friendly interface to most NLM data bases. This software can be adapted by the user to access AIDSLINE.

Douglas C. Jones

Kent Smith, Deputy Director of the National Library of Medicine, puts the Library's newest data base, AIDSLINE, through its paces.

An average search using GRATEFUL MED costs less than $5, including all communication and other charges. The software may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161. The cost is $29.95 plus $3 per order for shipping.

NLM also publishes a quarterly AIDS Bibliography that lists references by subtopics. Subscriptions ($12 domestic, $15 foreign) may be sent to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

For more information about AIDSLINE, GRATEFUL MED, and user codes, contact:
National Library of Medicine
MEDLARS Management Section
301-496-6193
Toll-free: 800-638-8480

Lawrence Berkeley Laboratory

Enzyme for Materials Synthesis Altered Through Manipulation of its Gene

CAM scientists, under the direction of J.F. Kirsch have succeeded in using genetic and protein engineering techniques to specifically alter the active site of the enzyme lysozyme for use in materials synthesis.

Lysozyme normally binds and catalyzes the degradation of polysaccharides such as the derivatives of cellulose found in bacterial cell walls. To use the enzyme for materials synthesis, its active, or substrate binding site must be altered so that it can bind synthetic sugars and polymerize them to make novel polymers. In order to perform this modification rationally, the mechanism by which the enzyme binds its substrate must be well understood. To elucidate this interaction, the gene for lysozyme, which had earlier been cloned and expressed by the CAM group, (Research Notes Vol. 1, No. 2) was altered in three ways. First, the two amino acids which participate in the enzyme's catalytic activity, aspartate 52 and glutamate 35, were replaced to allow isolated study of substrate binding in the absence of catalysis. Using the technique of site-directed mutagenesis, the 35th and 52nd codons of the gene were altered, leading to the replacement of the aspartate and glutamate with other amino acids that are not active in catalysis. As expected, activity was reduced 20-100 fold in each case; the mutant containing both changes has now been constructed and will be tested.

The third alteration involves aspartate 101 which binds the substrate and positions it for catalysis. It was replaced by a series of six other amino acids. The resulting enzymes were then studied for substrate binding. Binding energies have been calculated and the effect of amino acid size and charge, and solution pH evaluated. Continuing work is focused on using this information to select alterations that are best suited for binding the specific synthetic sugars selected as monomers for novel polymer synthesis.

For Additional Information:

Office of Research and Technology Application
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Berkeley, CA 94720
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Refer to CAM Volume 2, Number 1/TN

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Gene Transfers Quick Answers

Animal researchers in ARS have taken another step toward genetically engineered cattle that can resist disease, produce leaner meat or higher quality milk, or have other valuable traits.

"We have developed a biotechnology system that tells us if a gene injected into a fertilized egg is still present in the developing embryo before we implant the embryo into a surrogate animal mother," says molecular biologist Donna A. King at ARS' Beltsville, Maryland, research location.

"We take 25 or so cells from a cow or mouse embryo and mix them with an enzyme, polymerase, that acts as a 'copier machine.' If the gene we are looking for is there, the polymerase will make a million or more copies," King says.

"In this way we can make enough copies for existing tests to detect the new gene," she says. "Until now, researchers have had to wait until an animal was born to see if it still carried the gene inserted into it when it was an egg."

When working with mice—and their 21-day gestation period—scientists can afford to wait until offspring are born to see if an injected gene is still present. "But," she adds, "cattle, with their 280- to 285-day gestation period and costly feed bills, are another story."

By avoiding this delay, the new system could cut the cost of developing reliable gene engineering technology for farm animals, says King's colleague, animal physiologist Robert J. Wall.

"The problem," Wall says, "is that even though DNA—the stuff genes are made of—is placed in an egg, normal laboratory tests can't detect it in the embryo because there is so little of it."

Biologist Donna King examines a "signature" X-ray image of DNA generated by embryos carrying a foreign gene.

The new system, besides taking some of the hit or miss out of genetic engineering, could bring a tenfold increase in efficiency—30 cows could be used for the same tests that would have formerly required 300. "Perhaps more important," Wall says, "this system saves valuable time while assuring scientists that their gene engineering tests are on track."

Rita M. Dougherty is with USDA-ARS Biochemistry Research, Western Human Nutrition Research

For Additional Information:

Donna A. King and Robert J. Wall
USDA-ARS Reproduction Laboratory
Beltsville Agricultural Research Center-East
Beltsville, MD 20705
(301) 344-1500

Federal Laboratory Resource

NIH Research & Technology

U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Culture Collection of Mycological Germplasm

Coprincipal Investigator:
Shung-Chang Jong, Ph.D.
Head, Mycology & Botany Department
American Type Culture Collection
12301 Parklawn Drive
Rockville, Maryland 20852
(301) 881-2600

Director:
Robert E. Stevenson, Ph.D.

Resources Provided

- This center is the only general service collection of living fungi (including yeasts) in existence in the United States, consisting of 22,000 strains representing more than 5,000 species and 1,200 genera. The collection not only supplies reliable cultures but also provides full information on the background and properties of the strains.
- The collection also provides an identification service for specific strains isolated by field workers and acts as an information clearinghouse in all fields, both basic and applied, to answer inquiries about strains, nomenclature, classification, characterization, preservation techniques, and special applications of fungus cultures in systematics integrated with morphology, physiology, pathology, toxicology, molecular biology, genetics, ecology, evolution, and in the study and solution of human problems involving the health sciences, food and energy resources and the quality of the environment.

Research Emphasis or Application

- Research emphasis is on characterization and systematics, the effects of physical agents on sporulation, establishment of laboratory information management systems, and in finding improved methods of identifying, classifying and preserving cultures in a stable and unaltered condition. Members of the staff were among the first to do research on developing cryogenic storage in liquid nitrogen, which is now recognized as the most reliable means for preserving living fungi. With this technique, scientists, teachers and students are now assured of the ready availability of reliable living fungi in pure culture.

Federal Laboratory Resource

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Laboratory Marsupial for Biomedical Research

Principal Investigator:
John L. VandeBerg, Ph.D.
Chairman, Genetics Department
Southwest Foundation for
Biomedical Research
P.O. Box 28147
San Antonio, Texas 78284
(512) 674-1410

Resources Provided

To Outside Investigators

- *Animals:* Juvenile and adult gray short-tailed opossums (*Monodelphis domestica*) are available for sale to qualified investigators. Limited numbers of Virginia opossums (*Didelphis virginiana*) are also available for sale from time to time.

To Collaborating Scientists and Graduate Students

- *Eligibility:* Those wishing to conduct research at this facility must have their projects reviewed by the principal investigator.
- *Services:* Services are provided without charge to collaborating scientists, or on a fee basis depending on the extent of the service required and of the resources available at this facility. Services that can be provided include complete animal husbandry, medical care, pathology, clinical chemistry, anesthesiology, blood collection, immunization, electrophoretic analyses, and serologic analyses. Timing of conception can be determined for experiments requiring timed pregnancies.
- *Animals:* The breeding colony contains approximately 1,000 adult and juvenile *Monodelphis domestica* and 30 adult and juvenile *Didelphis virginiana*. Accurate pedigree records have been maintained from the time of introduction of the animals into captivity; some pedigrees consist of 12 generations.
- *Contact Person:* John L. VandeBerg, Ph.D., (512) 674-1410.

Research Emphasis or Application

- *Basic Objective:* To develop a species of small marsupials as an economical and convenient laboratory animal for biomedical research.
- *Current Research:* The marsupial colony is being used in projects involving nutritional requirements, timing of developmental events, cytogenetics, immunogenetics, biochemical genetics, X chromosome inactivation, inbreeding, and reproductive endocrinology.

NIH
Research & Technology
Federal Laboratory Resource
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

MICROMED: A National Resource for Intermediate Voltage Electron Microscopy

The new MICROMED facility at the Bowman Gray School of Medicine in Winston-Salem, North Carolina-the first intermediate voltage electron microscopy (IVEM) laboratory in the nation dedicated to medical research-provides an integrated approach to ultrastructural studies of biomedical samples. This new technology enables researchers to detect changes in a cell of a more subtle nature than has been possible before, which may prove beneficial in the development of treatments for and prevention of problems such as heart disease and acquired immune deficiency syndrome, according to Dr. Jon C. Lewis, professor of pathology and director of the resource.

This unique resource combines state-of-the-art instrumentation and associated technical and consulting services with user education. MICROMED's current research focus is on ultrastructural studies of blood coagulation, incipient atherosclerosis, biological response modifiers, and viral infection.

Using IVEM investigators can obtain high resolution images of relatively thick specimens (0.5 to 2.5 micrometers). The added feature of stereomicroscopy allows researchers to view the intracellular architecture of the entire specimen in three dimensions.

IVEM operates at 300,000 to 400,000 electron volts, compared to 80,000 to 100,000 volts in a conventional electron microscope. Dr. Lewis says that in theory the power of the microscope permits viewing objects slightly larger than a hydrogen atom.

The facility is a national resource supported by the Biomedical Research Technology Program of the NIH Division of Research Resources. It opened in May 1988 and was established in part by funding provided by the Biomedical Research Support Shared Instrumentation Grant Program of the NIH Division of Research Resources; by the National Heart, Lung, and Blood Institute; and by the National Cancer Institute to provide core facilities for research on atherosclerosis and cancer. The center also is supported by the North Carolina Biotechnology Center, Bowman Gray School of Medicine, and Philips Electronics Instruments, Inc.

The heart of the facility is the new Philips CM30, a second-generation intermediate voltage electron microscope. MICROMED's CM30 was the first of a new type of electron microscope to be shipped from the manufacturer in Holland, Dr. Lewis says.

In the atherosclerosis study, Dr. Lewis is studying changes that occur inside cells of the artery wall in the early stages of the disease. IVEM provides the advantage of looking at the changes in three dimensions, which may accelerate understanding of the disease process and progress toward lowering the number of deaths resulting from heart disease.

Their IVEM study of secondary infections in children following influenza has yielded a key to yet another puzzle. They found that the influenza virus inactivates a vital component in normal immunity, the neutrophil, a white blood cell. This sometimes causes children who have had a simple bout of influenza to develop life-threatening secondary infections.

The center houses a complete spectrum of electron microscopes and specimen preparation equipment for all aspects of electron microscopy, including instruments for cryosectioning. Darkrooms are available for film processing, micrograph printing, and stereo projection slide preparation. Research and office space are provided for visiting researchers.

In the future Dr. Lewis would like to make the resource available to more researchers with a wide range of medical interests. His long-range objective is to interface the IVEM facility with a microwave transmission system, making it possible to send images around the world.

"I'm hopeful that we can activate this vision within a 5-year framework," he says. "Wouldn't it be exciting for a pathologist from Denver to be able to share electron micrographs with a pathologist from Bowman Gray in real time?"

FOR ADDITIONAL INFORMATION: For more information on the IVEM resource, contact: Dr. Jon C. Lewis, MICROMED, Bowman Gray School of Medicine, 300 S. Hawthorne Road, Winston-Salem, North Carolina 27103; Telephone: (919)748-2675

NIH
Research & Technology
Federal Laboratory Resource
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Protein Data Bank and Data Evaluation Studies

The Protein Data Bank at Brookhaven National Laboratory in Upton, New York, the only data base providing comprehensive information on three-dimensional structures of biological macromolecules, is an essential computer tool in many biomedical research programs.

Investigators from throughout the world apply the data to their studies involving crystal structure analysis, drug-receptor binding, protein engineering, and a number of other areas of biomedical research dealing with the structure and function of macromolecules.

"Every time we learn something about a new structure, we are expanding the knowledge of how living things function on the molecular level," says Dr. Thomas Koetzle, principal investigator of the Protein Data Bank.

According to Dr. Koetzle, advances in the field of crystallography and a dramatic increase in the number and types of structures deposited in the data base during the past 15 years have made the service indispensable by providing the only practical way to preserve these structures for use by the scientific community.

"Our primary focus is to receive data, digest it, put it in a uniform format, subject it to an extensive battery of tests to make sure that it does not have inconsistencies, and eventually release information as part of a data base to the scientific public," he says. "The mission of the Protein Data Bank also involves improving the utility and accuracy of the data base."

The Protein Data Bank was established in 1971, when only a few protein structures had been determined at the atomic level. The data base has grown dramatically in the number and diversity of structures from seven proteins at the outset to more than 350 structures today. It also includes nucleic acids, transfer RNA molecules, polynucleotides, model DNA structures, coat protein structures of virus particles, and polysaccharides.

Funding for the data base is provided by the National Institutes of Health and the National Science Foundation. An inhouse research project is being supported by the NIH Division of Research Resources, while the NSF provides core support for the maintenance of the Protein Data Bank, supplemented with funding from the National Institute of General Medical Sciences. The institution where the data base is located, Brookhaven National Laboratory, operates under a contract with the U.S. Department of Energy.

The inhouse research currently being conducted involves evaluating protein structural data and searching for statistical measures of precision of the data. This research is leading to an improved understanding of the accuracy of the protein structural data, which should result in improved quality and utility of the resource, Dr. Koetzle says.

The data base is vital to research in the forefront of the

biomedical field today. One avenue of study in the area of pharmacology uses the data base to explore the rational design of drugs using energy calculations and computer graphics. With these methods, an inhibitor molecule and an enzyme of known structure can be docked together to investigate the predicted effects on binding of modifying functional groups of the inhibitor.

Two classes of information—atomic coordinates and crystallographic structure factors and phase angles—are collected, stored, and distributed from the data base together with extensive citations to the literature. All data are stored on magnetic tape and distributed on tape or microfiche. A number of computer programs that operate on the atomic coordinate entries, primarily FORTRAN, are available. In programs designated "supported," the Protein Data Bank staff will provide corrections for demonstrated errors.

Distribution of the Protein Data Bank is conducted from the main location at Brookhaven National Laboratory with subsidiary distribution centers in Osaka, Japan, and East Melbourne, Australia. About 400 copies on tape are distributed each year from Brookhaven to researchers throughout the world at a cost of approximately $300 per copy. A quarterly Protein Data Bank Newsletter distributed to users includes information on data and documentation currently available in the data base.

Investigators who wish to deposit structural data are asked to submit a deposition form (available from Brookhaven) listing information essential to preparing the entry. The data are then converted to a standard format and exhaustive checks are run on each Data Bank entry to ensure maximum reliability.

The Brookhaven facility operates with four fulltime professional staff (Dr. Enrique Abola, crystallographer; Dr. Stephen Bryant, postdoctoral fellow; Frances Bernstein, computer science analyst; and Jenny Weng, programmer) and one part-time administrative assistant (Pamela Esposito) under the direction of Dr. Koetzle.

Some scientific journals require or strongly encourage investigators to deposit numerical data in the Data Bank before their articles on macromolecular structure can be published. According to Dr. Koetzle, an increasing number of journals are adopting similar policies to ensure the dissemination of information regarding these structures.

A recent development of the Protein Data Bank is the addition of online distribution capabilities. Centers currently are being established in Canada, Europe, and the United States through which investigators can access the network and load structures directly into their computers. One goal of the Data Bank, Dr. Koetzle says, is to increase and further improve online communications.

It has been projected that more than 100 new structures will be added to the Protein Data Bank in 1988. Fifty structures were added in the first half of the year, and it is expected that the number of new structures will double by the end of the year. This would elevate the total number of structures in the Data Bank to more than 400.

"This is a significant increase in the number of new structures when compared to a previous average annual increase of only about 25 new structures," Dr. Koetzle adds.

Dr. Koetzle hopes that in the future the Data Bank can be upgraded from the current archival file system, in which each entry is stored as a separate file, to a relational data base format, in which information can more readily be searched and compared.

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NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Technique for Sorting Cells According to Age

When cells divide they go through a series of steps called the cell cycle during which they grow bigger and synthesize DNA in preparation for the actual separation into two new cells. A growing culture contains a mixture of cells at different steps in the cycle, varying in size and DNA content. Investigators at the Los Alamos National Laboratory in New Mexico have developed an instrument for sorting such a mixture of asynchronously growing cells into compartments of cells having the same size and therefore the same age. This instrument is based on the first volume-sensing flow cell sorter, also developed at Los Alamos. They developed the method to assess variation in survival of cells of different ages after exposure to radiation or chemical agents.

The cells are sorted by the instrument after they pass through an orifice containing an electronic volume-sensing device, according to principal investigator Dr. James P. Freyer of the Life Sciences Division. The method requires no special preparation of the cells, which can be held in complete growth medium at any desired temperature during sorting, and sorting the cells for an age-response curve only takes 2 hours, he says. Dr. Freyer and his colleagues, Mark E. Wilder and Dr. Mudundi R. Raju, have tested the method on several different cell lines and report a good correlation between volume and cell age for almost all of them. "A significant aspect of the technique is the rapid plating of cells onto a culture dish and our ability to use the same technique on six or seven different cell lines," Dr. Freyer says.

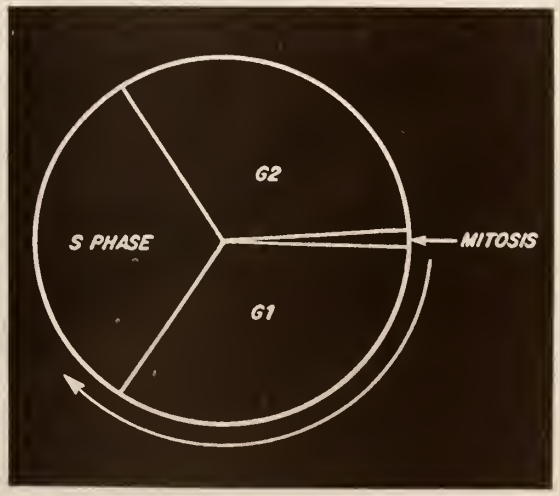
The new cell sorter contains a special flow cell that incorporates an internal Coulter-type electronic volume-sensing orifice. Cell suspensions are placed in centrifuge tubes, loaded into the sample chamber of the instrument, sorted directly into petri dishes containing culture medium, and their ability to form colonies is assessed.

The investigators correlate the relationship between cell volume and position in the cell cycle by measuring the DNA content of cells isolated from different volume regions. In this method cells are stained with a fluorescent dye that binds to DNA (mithramycin) after being sorted by volume. The degree of fluorescence, measured by laser excitation, is correlated with the volumes of the sorted cell subpopulations.

The Los Alamos investigators have calibrated the amplifier settings with actual volume measurements of fluorescent microspheres of known sizes. After calibration, cell volumes of 200 randomly selected cells measured microscopically were within 2 to 3 percent of the volumes measured electronically. To further establish the correlation between position in cell cycle and cell volume, exponentially growing cells were incubated with radioactively labeled thymidine, a precursor of DNA, and then volume-sorted. The extent of DNA synthesis as a function of cell volume corresponded to the expected position in the cell cycle.

The cell cycle consists of four phases. In the G1-phase the cells prepare themselves for the DNA synthesis that takes place in the S-phase, and in the G2-phase, which follows the S-phase, they prepare themselves for the actual division or mitosis (M) that results in two new cells. There was a good correlation between cell volume and age in three cell lines of Chinese hamster fibroblasts, in Chinese hamster ovary (CHO) cells, and in EMT6/Ro mouse mammary tumor cells. Unsorted fibroblasts contained 44 percent cells in G1-phase, 42 percent in S-phase, and 14 percent in G2 plus M-phase.

After sorting, the researchers obtained an almost pure population of G1-phase cells and a good separation of S and G2 plus M-phase cells. For all cell lines the G1-phase cells were of



The mammalian cell cycle—a series of steps a cell must go through before it can divide—consists of four phases. In the G1-phase the cell prepares itself for the DNA synthesis that takes place in the S-phase, and in the G2-phase, which follows the S-phase, it prepares itself for the actual division, or mitosis, that results in two new cells.

the highest purity. According to the investigators, the purity of the cell preparations corresponds well to that obtained with other methods.

The Los Alamos investigators use the cell sorting method to study whether cells at different phases of the cell cycle are equally sensitive to X-irradiation by irradiating cell suspensions and sorting them immediately after. "Measurements can be done rapidly since no cell cycle progression is necessary to obtain cells from all cell age compartments. In addition, the cells can be held at an optimal growth temperature (37° C)," Dr. Freyer says.

For all the cells, they found that the minimum radiation survivability is at the boundary between the G1- and S-phases and the maximum survivability at late S-phase, as indicated by the cells' ability to form colonies in the petri dishes in which they were collected. It is especially important that the sorting procedure is able to separate cells at the G1/S-phase boundary from those in late S-phase because the maximum change in radiation sensitivity is often observed in this area. The age response to very-low-energy x rays is a unique use of the method, according to Dr. Freyer. "What makes this so unique is that it is possible to use asynchronously growing cultures. There is no way to irradiate synchronized cell populations with these low-energy x rays," he explains.

One drawback of the method is that it is not possible to separate large batches of cells in one operation. "It is excellent for measuring survival, enriching populations, and selecting cells from different positions in the cell cycle for plating, but it is not a preparative technique," he says. However, he points out that a preparative instrument is being developed; this will make it possible to produce large numbers of cells in a particular phase, which currently cannot be done.

He also emphasizes that the sorting technique cannot be used to measure the cytotoxic effects of treatments that alter the cell volume distribution. "It is necessary that there is a good correlation between cell volume and the cell's position in the cell cycle," he states. For some cell lines, such as 10T1/2 mouse fibroblasts and human skin fibroblasts, the correlation is not satisfactory.

"The instrument is located at the Los Alamos National Laboratory and anyone is welcome to come and use it," Dr. Freyer states. He says that cell biologists and radiobiologists already have used the technique, and investigators studying cell responses to radiosensitizing agents have shown an interest. It is not possible to accommodate more than two visitors at a time because Dr. Freyer and his colleagues use the instrument several times weekly. Appointments to use the cell sorter are made by contacting Dr. Freyer; use of the instrument is free.

Additional reading:

1. Freyer, J. P., Wilder, M. E., and Raju, M. R., Rapid assay for cell age response to radiation by electronic volume flow cell sorting. *International Journal of Radiation Biology* 52:91-106, 1987.

2. Freyer, J. P., Wilder, M. E., and Raju, M. R., Coulter volume cell sorting to improve the precision of radiation survival assays. *Radiation Research* 97:608-614, 1984.

The work described in this article was supported by the National Flow Cytometry Resource of the NIH Division of Research Resources, the National Cancer Institute, and the US Department of Energy.

For Additional Information:

To locate information or professional contacts on this effort, contact:

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Refer to Volume XII, No. 12/TN

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Licensing Opportunity

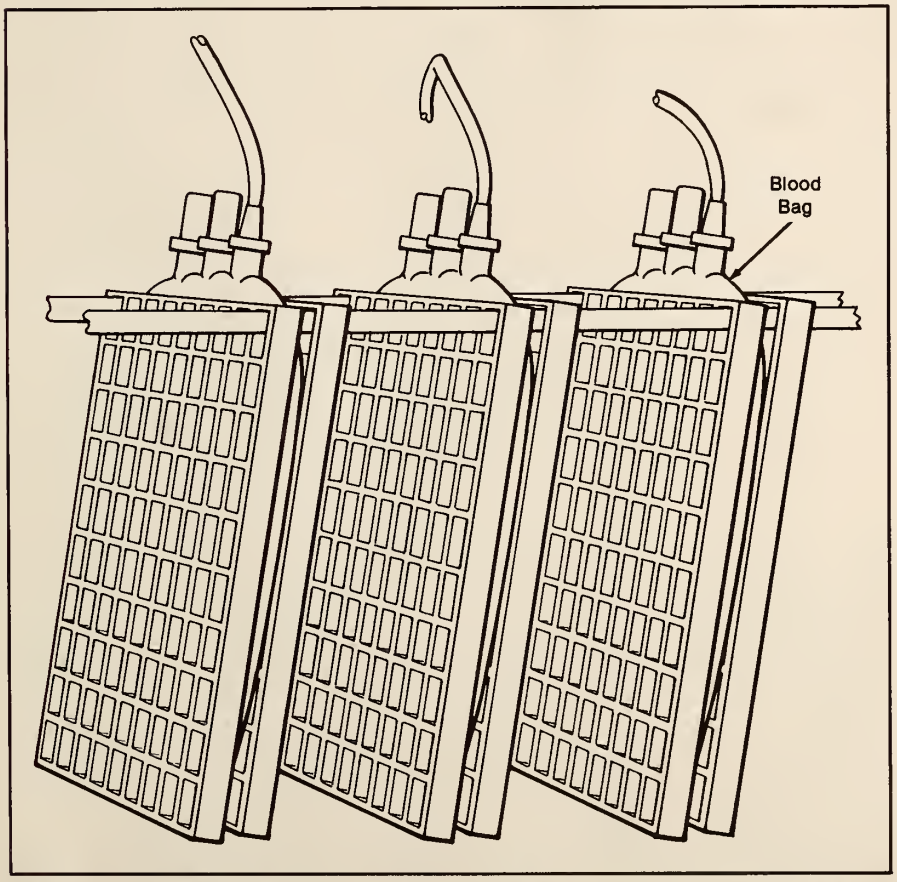
Extending the Shelf Life of Blood Platelets

Storing the platelet suspension in a thin layer allows the exchange of metabolic gases.

A new method of storing human blood platelets extends their vitality for transfusions. The method ensures that platelets receive ample oxygen and that expiratory carbon dioxide from the platelets is removed before the pH drops to harmful levels.

The platelets are packaged as a suspension in sterile liquid in plastic blood bags. Each bag is placed between a pair of plastic grids, and rubberbands are placed around the sandwich thus formed to hold it together. The sandwiches are stored upright (see figure) in open air or in a container through which air is pumped at a rate of at least 45 L/min.

The grids compress the bag to a uniform ⅛-in. (0.3-cm) thickness, thin enough that air diffusing through the plastic bag can penetrate to the innermost platelets and that carbon dioxide can readily leave the inner region and diffuse through the bag to the outside. Without the support of the grids, a bag would sag and distend at its bottom to about ½-in. (1.3-cm) width. This thickness prevents the effective exchange of gases, and the platelets quickly deteriorate when they are stored this way.



Flattened by Grids, standard blood bags allow air to enter and nourish blood platelets and allow carbon dioxide and other metabolic wastes to expire through the bag. As an added benefit, the inexpensive grids make the blood bags easier to handle.

The grids are strong and rigid but open enough to provide a large area of contact between the bag and external air. The solid mass of a grid occupies only 16 percent of the 13- by 14.5-cm grid area.

The grid-sandwich storage method makes it unnecessary to agitate blood bags to induce gas circulation. Bag agitation is virtually impossible when the bags are transported between storage places, and agitation itself tends to destroy some platelets. In 7-day comparison tests, the posttransfusion yield and survival of the platelets stored in grids without agitation were equal to those of platelets stored in uncompressed but agitated blood bags.

This work was done by Douglas M. Surgenor of The Center for Blood Research for **Johnson Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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The Center for Blood Research
800 Huntington Avenue
Boston, MA 02115

Refer to MSC-21157/TN

Lyndon B. Johnson Space Center
Houston, TX 77058
Technology Utilization Officer: Dean C. Glenn
Mail Code EA4
(713) 483-3809
Patent Counsel: Edward K. Fein
Mail Code AL3
(713) 483-4871

Natural Resources Technology & Engineering

0412 Aeromagnetic Surveys in the United States

0413 New Global Weather Prediction Model Now Operational

0414 Radar Detects Ocean Surface Currents—An interferometric system uses reflections from ripples.

Other Items of Interest

0379 Three-Dimensional Finite-Element Model of Water Flow Through Saturated-Unsaturated Media

NOAA Technology Brief
National Oceanic and Atmospheric Administration

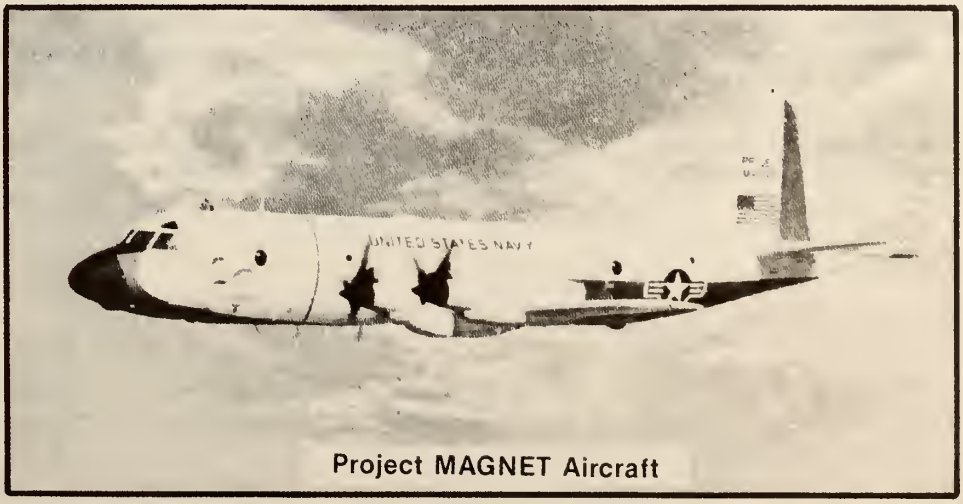
Aeromagnetic Surveys in the United States

In an effort to provide a central library for digital aeromagnetic data in the public domain, the National Geophysical Data Center (NGDC) is continuing to assimilate new digital data from aeromagnetic surveys in the United States. The data, compiled from numerous individual surveys, have been added to a data base that now includes about 30 million observations. The data cover a range of years and are available in several different formats.

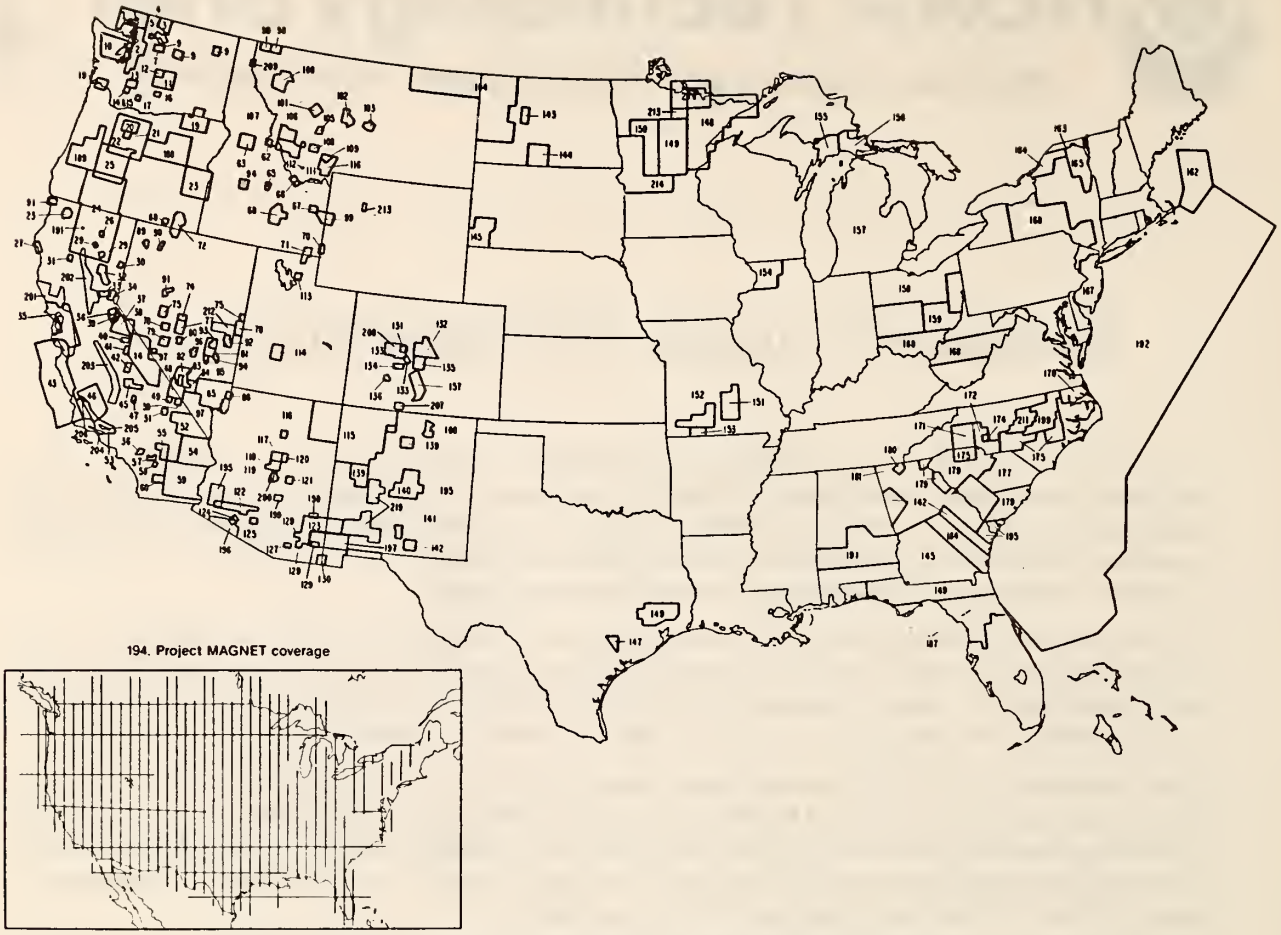
The altitude, line spacing, and density of the data vary from survey to survey. Generally, however, the line spacing is 0.5 to 5 km, the altitude above ground is 0.5 km, and the sampling interval along flight lines is 1 second. Sensitivity of the instruments is commonly about 1 nanotesla. Most of the surveys were conducted after 1970, and have been organized by geographic region.

Major contributors to this important data base include the U.S. Geological Survey, U.S. Naval Oceanographic Office, U.S. Naval Research Laboratory, Minnesota Geological Survey, Oregon State University, Woods Hole Oceanographic Institution, and Michigan State University. The philosophy of exchange of data from the NGDC archive for new contributions has stimulated many organizations to transfer their data holdings to the Data Center.

NGDC continually explores new frontiers in data storage. These presently include compact discs and a variety of magnetic media storage. Inquiries on format options are invited. One of NGDC's compact discs, *Geophysics of North America*, includes a diverse selection of gridded spatial data such as magnetics, gravity, topography, and satellite imagery. For information on this product, telephone (303) 497-6591.



Project MAGNET Aircraft



194. Project MAGNET coverage

Aeromagnetic survey data available for the conterminous United States.

For more information on surveys contact Ronald W. Buhmann National Geophysical Data Center NOAA, Code E/GC1, 325 Broadway, Boulder, CO 80303, (303) 497-6128.

NAVY
Domestic Technology Transfer Fact Sheet

New Global Weather Prediction Model Now Operational

A new weather prediction model, developed by the Naval Environmental Prediction Research Facility (NEPRF), a field activity of the Office of Naval Research, has now gone into operational use at Fleet Numerical Oceanography Center. The new Navy Operational Global Atmospheric Prediction System, NOGAPS 3.0, is a significant upgrade of a previous system, NOGAPS 2.2, which was developed more than five years ago, also at NEPRF.

The NOGAPS 3.0 computer data is the basis of virtually all the atmospheric and ocean forecasts generated by the Fleet Numerical Center. These include computer models to make regional forecasts of atmospheric conditions, ocean wave and acoustical forecasts, prediction of Navy regional forecast centers and Navy ships to provide accurate assessment of ever-changing ocean and atmospheric conditions.

The new system makes global atmospheric predictions twice each day by assimilating more than 300,000 weather observations gathered from around the world and from both geostationary and polar orbiting satellites. These predictions have proven able to forecast global ice motion and thickness, optimum routes for ships and aircraft as well as numerous tactical applications such as search and rescue, or wind prediction for ballistic guidance and chaff dispersion. These predictions are distributed to environmental conditions from the surface to 30-kilometer elevation as much as five days into the future. This provides at least a 24-hour improvement over previous forecasting accuracy.

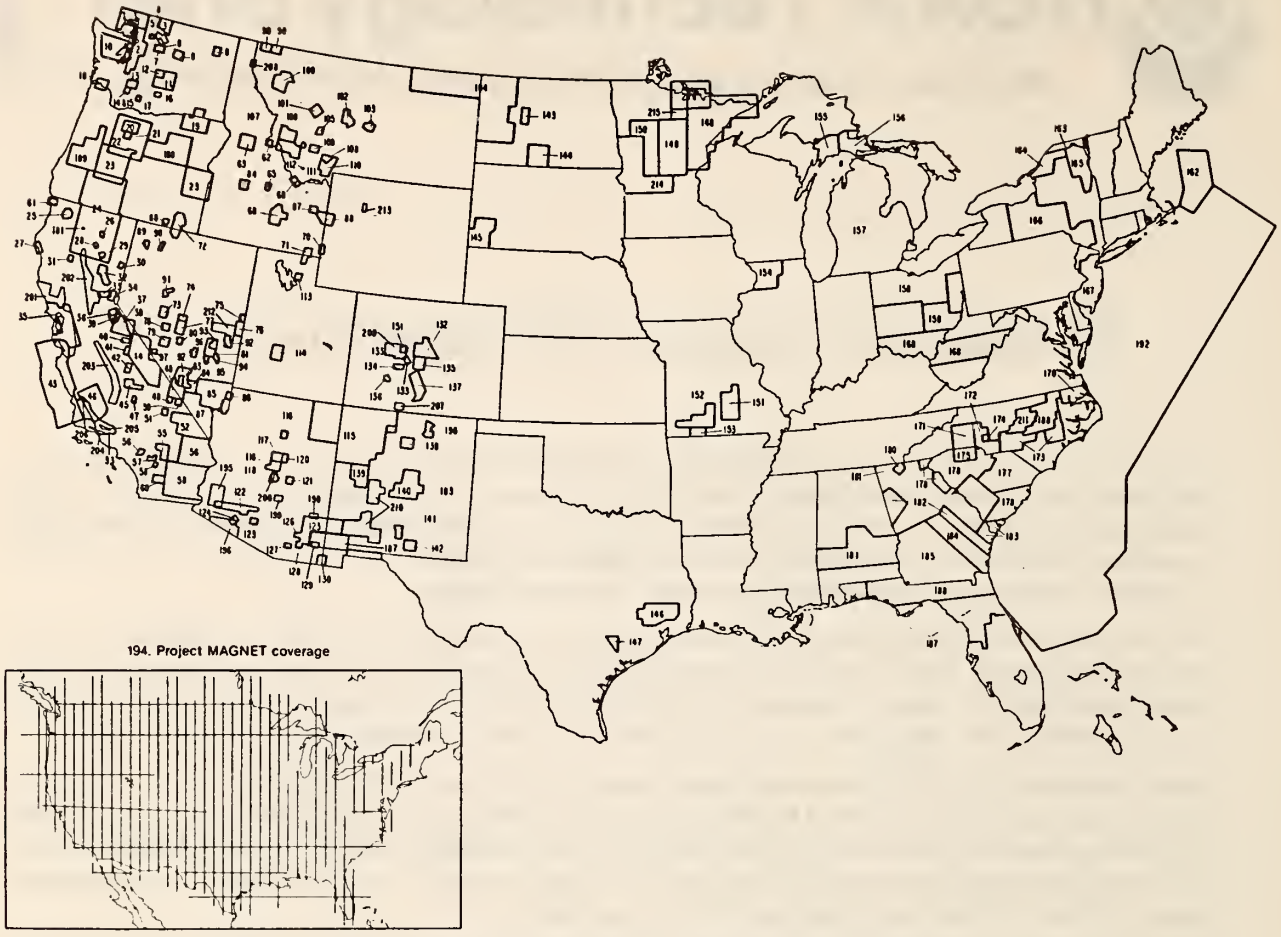
The NOGAPS 3.0 computer data combines a numerical prediction model with weather observations to create an ordered description of the momentum and mass of the atmosphere. The numerical model determines the effects of atmospheric processes that are difficult to measure, such as solar and earth radiation, clouds, upper atmospheric turbulence, rain, soil moisture, ground-water runoff or the effects of mountain ranges.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 131202/TN



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Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 131202/TN

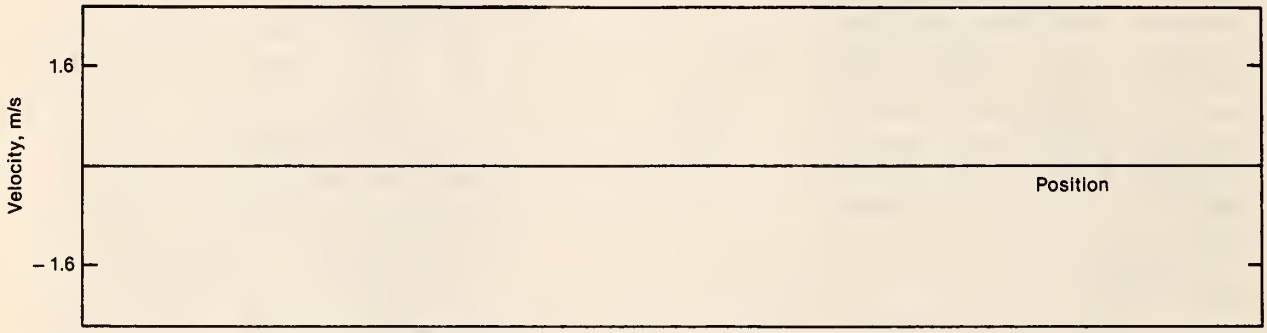
NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Radar Detects Ocean Surface Currents

An interferometric system uses reflections from ripples.

An experimental airborne interferometric synthetic-aperture radar system measures the line-of-sight component of the velocity of ripples on the surface of the ocean. With the help of suitable assumptions about the relationships among the ripples, the larger waves or swells on which they occur, and the overall movement of the water, the component of velocity of the underlying surface current perpendicular to the path of the airplane can be deduced.

The radar detects ripples oriented perpendicularly to the radar line of sight and for which the projection of the surface wavelength along the line of sight equals



The East/West Component of the ocean-current velocity was computed from the radar returns at a 37° angle of incidence of the radar line of sight. The horizontal scale represents the position along a north/south flightpath about 11 km long.

half the radar wavelength (Bragg reflection condition). The radar return is phase shifted by an amount proportional to the projection of the velocity of the ripples along the line of sight.

The system is essentially a synthetic-aperture radar equipped with two antennas separated by distance B along the direction of motion. The signals from the two antennas are processed separately into two images, which are then combined interferometrically to obtain maps of velocity. The motion of the ripples toward or away from the radar causes a phase difference, ϕ, between corresponding picture elements in the two images. This difference is proportional to the radial distance moved by a resolution element in the time required for the rear antenna to move to the position formerly occupied by the front antenna:

$$\phi = 2a\pi uB/\lambda v$$

where u = the line-of-sight component of the ripple velocity, λ = the radar wavelength, v = the velocity of the radar along the ground, and a = 2 if both antennas transmit and receive or 1 if one antenna transmits but both receive.

The experimental system, using λ = 24.5 cm, was tested aboard a CV-990 airplane with the two antennas separated by B = 18.5 m, with the rear antenna transmitting. Flying southward at an altitude of 26,000 ft (7.9 km) and a velocity of 461 kn (237 m/s), the system generated images of the San Francisco Bay region, showing peak east/west velocities of 1.6 m/s (see figure). (A velocity of 2.6 m/s was expected from tidal-current tables.)

Because the experimental images show no overall motion of the surface of the ocean (apart from the currents), it appears that each resolution element contains nearly-equal Bragg-component ripples traveling toward and away from the radar. Presumably, the two sets interact to form standing waves in the reference frame that moves with the current.

This work was done by R. M. Goldstein and H. A. Zebker of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-17192/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Physical Sciences

0415 Double Rotation: "New Angles" in NMR Spectroscopy (Licensing Opportunity)

0416 Major Expansions Made to Mass Spectral Database

0417 Temperature Measurement from 1300K to 6000K (Licensing Opportunity)

0418 Gas-Jet Cooling Would Improve Czochralski Process—The diameter of the growing crystal would be more stable and controllable. (Licensing Opportunity)

0419 Managing Data from Signal-Propagation Experiments—Computer programs generate characteristic plots from amplitudes and phases.

Testing & Instrumentation

0420 Method of Generating Chemiluminescent Light

0421 High-Efficiency Scintillation Detector for Thermal and High-Energy Neutrons

0422 Monochromator for Continuous Spectrum X-Ray Radiation

0423 Chopping-Wheel Optical Attenuator—A rotating star-shaped wheel provides adjustable attenuation independent of wavelength.

Other Items of Interest

0374 Pulsed-Aerosol Analyzer

0377 Optical Sensor of High Gas Temperatures—A contact pyrometer resists effects of heat, vibration, and moisture.

0390 High Temperature Materials Laboratory

0392 Millimeter Size Single Crystals for Superconducting $YBa_2Cu_3O_x$

0402 X-Ray Methods for Analyzing Rough Wear Surfaces

Technology Application

Lawrence Berkeley Laboratory

Double Rotation: 'New Angles' in NMR Spectroscopy

An ingenious new way to use nuclear magnetic resonance (NMR) to study solid materials has been developed.

The new method, known as Double Rotation (DOR) NMR, involves spinning a sample around two axes at the same time, like a top within a top.

The DOR technique will greatly extend the range of NMR, one of the most powerful tools of modern science. It can improve up to 100 times the accuracy with which scientists can distinguish between different specific locations and positions of atoms in a solid.

The new double rotation (DOR) technique, spectral resolution for nonspherical nuclei is as good as that previously obtained for spherical nuclei.

DOR is accomplished by rotating the sample inside a holder that rotates simultaneously on a second axis. The cylindrical holders are suspended on air bearings and driven by air jets to rotation speeds of 6000 hertz (about half a million revolutions per minute).

The result is two "magic angles" -- the conventional one of 54.74 degrees plus a new magic angle of 30.56 degrees. This complex motion has the effect of averaging out virtually all of the smearing effects that limited the study of solids in the past.

DOR extends NMR spectroscopy to the analysis of many technologically important solid materials. Spectral line width for sodium-23 was reduced by DOR to 75 Hz (from 12,000 Hz for static NMR spectroscopy and 4000 Hz for conventional magic angle spinning). In follow-up work, similar results for oxygen-17 and aluminum-27 has been reported.

The results involving oxygen-17 are of particular importance because many oxides (compounds of oxygen) exhibit superconductivity--the ability to carry electrical current without loss due to resistance--at relatively high temperatures. Studies with DOR may permit, for the first time, a detailed look at what is taking place at the oxygen sites in these materials.

FOR ADDITIONAL INFORMATION: Public Information Department, Lawrence Berkeley Laboratory, Berkeley, CA 94720; (415) 486-5771.

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Major Expansions Made to Mass Spectral Database

More than 6,000 new analytical mass spectra have been added to the NIST/EPA/MSDC Mass Spectral Database, a major international resource for analytical chemists and environmentalists to use in identifying unknown substances. It now contains approximately 50,000 chemical compounds, and for the first time, information is included on the structures of more than 40,000 of these compounds. The database can be purchased for use on personal computers (PCs) or leased in a magnetic-tape format for scientific instruments. The major improvements to the PC version include new software options for faster searches, a special feature for developing a personal analytical mass spectra data file, and new computer graphics that show the molecular structures of approximately 40,000 compounds. The magnetic-tape format now contains both spectral and structural data.

FOR ADDITIONAL INFORMATION: The new PC Version 2.0 is available for $975. Users of PC Version 1.0 may upgrade for $225. To order, contact the Office of Standard Reference Data, A320 Physics Bldg., NIST, Gaithersburg, Md. 20899; telephone 301/975-2208.

NIST Technology Update

National Institute of Standards & Technology
(Formerly the National Bureau of Standards)
U.S. Department of Commerce, Gaithersburg, MD 20899

Temperature Measurement from 1300K to 6000K

Trying to measure the melting point of graphite at atmospheric pressure is a lesson in disappearing acts. The graphite evaporates! A NIST research has developed a technique to avoid that problem with a measuring system that allows investigation of materials properties at temperatures ranging from 1300 K to 6000 K. Even 10,000 K is within reach of the system. Practical applications include space-related work, where temperatures soar during reentry, nuclear reactor safety, and defense, specifically rocketry. The secret to the system, which took 10 years to design, develop, construct, and make operational, is extremely rapid measurements, taken in microseconds (millionths of a second). The rationale is that if you conduct the experiment in a very, very short time, many measurement problems associated with hostile environments, while still present, are minimized.

FOR ADDITIONAL INFORMATION: Contact Dr. Ared Cezairliyan, NIST, HAZ-A124, Gaithersburg, MD 20899; (301) 975-5931.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Gas-Jet Cooling Would Improve Czochralski Process

The diameter of the growing crystal would be more stable and controllable.

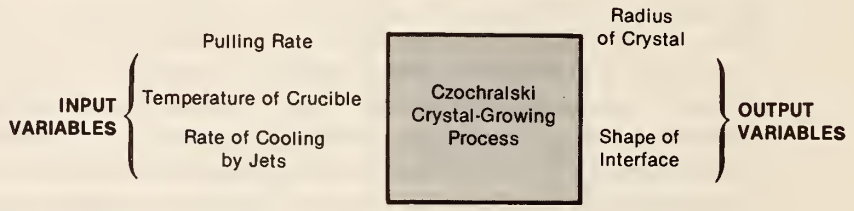
Controlled cooling by jets of gas would improve the growth of single crystals of silicon by the Czochralski process, according to a recent theoretical study. The rate of cooling by jets thus joins the temperature of the crucible and the pulling rate as an input variable of the process that can be adjusted to achieve the required diameter of the crystal and shape of the crystal/melt interface (see figure).

The mathematical model of the process takes account of the following major thermal effects in the vicinity of the interface:

- The conduction of heat from the interface into the crystal,
- The conduction of heat from the melt across the interface into the crystal,
- Convective cooling of the crystal and of the surface of the melt by the jets of gas blowing horizontally just above the wall of the crucible, and
- Radiative cooling of the side of the crystal.

In addition, the calculations include the effects of the pulling speed, the shape of the crystal/melt interface, and the shape of the melt/gas meniscus. The effects of convection in the melt and of the rotation of the crystal are ignored.

Both simple analytical approximations and detailed numerical simulations show that cooling by jets offers some important advantages: It can increase the pulling rate at a given diameter, thus increasing productivity. The shape of the interface and the diameter are more stable than in a system without jets, and either can be controlled solely by adjusting the rate of flow through the jets. In addition, the control of the shape of the interface and the diameter by varying the flow rate is more effective than control through adjustment of the pulling rate or of the temperature of the crucible. Furthermore, both the shape of the interface and the diameter can be controlled simultaneously by adjusting the flow rate and either the temperature or the pulling rate.



The Critical Parameters of the Growing Crystal (the output variables of the Czochralski process) can be controlled via two or all three of the input variables. One of the input variables (usually pulling speed) can be held constant while the other two are adjusted to achieve the required diameter and interface.

To achieve uniform doping of the crystal, it is necessary to maintain a planar interface. One of the disadvantages of cooling by jets is a tendency to produce concave interfaces. Other disadvantages include difficulties in maintaining axisymmetry and localized high thermal gradients, which increase thermal stresses and, consequently, give rise to dislocations in the crystal. The concavity of the interface can be minimized by controlling all three input variables. Axisymmetry can be promoted by the use of multiple jets around the crystal. The flow of gas will probably have to be restricted to moderate levels to realize all of its potential benefits.

This work was done by M. P. Dudukovic, P. A. Ramachandran, and R. K. Srivastava of Washington University for **NASA's Jet Propulsion Laboratory**.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to Washington University. Inquiries concerning licenses for its commercial development should be addressed to

Washington University
Chemical Engineering
Campus Box 1054
One Brookings Drive
St. Louis, MO 63130

Refer to NPO-17272/TN

Jet Propulsion Lab.
NASA Resident Office
Technology Utilization Officer: Gordon S. Chapman
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(818) 354-4849
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(818) 354-2734
Technology Utilization Mgr. for JPL: Norman L. Chalfin
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Pasadena, CA 91109
(818) 354-2240

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Managing Data From Signal-Propagation Experiments

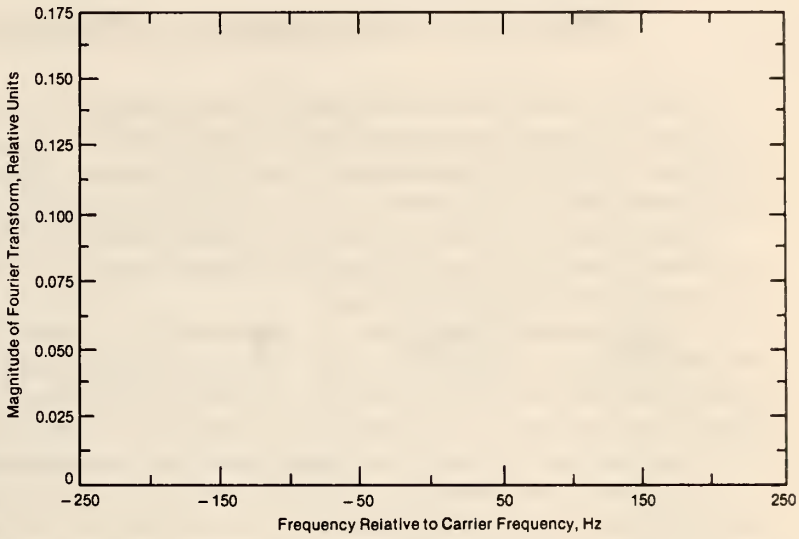
Computer programs generate characteristic plots from amplitudes and phases.

A software system enables a minicomputer to process data on the amplitudes and phases of signals received during experiments in ground-mobile/satellite radio propagation. The system takes advantage of the file-handling capabilities of the UNIX operating system and the C programming language. The system interacts with the user, under whose guidance programs in the FORTRAN language generate plots of spectra or other curves of the types commonly used to characterize signals.

In the particular experiments for which the system was devised, signals received at 896 MHz are split into an in-phase channel and a quadrature channel, in each of which the amplitude is sampled 1,000 times per second. With the help of a calibration table, these raw data are preprocessed into equivalent data on the power (or amplitude) and phase.

The preprocessed data are organized into files, each of which consists of a sequence of 63 records of 4,120 bytes or 2,060 integers apiece. Each record contains a sequence of 1,024 samples (thus representing 1.024 s of observation time). In addition to the amplitudes and phases, each record also contains a 24-byte or 12-integer header that specifies such ancillary parameters as the type of antenna, the time of day, and the speed of the receiving vehicle.

For efficiency, the files are stored in binary format and must be converted to the ASCII format for display or for further processing. A small program in the C language can be used to convert these or any binary sequential files into the equivalent ASCII files.



The Fourier Transform, a measure of the amplitude spectrum, is computed from a sequence of 1,024 in-phase and quadrature samples of the input signal.

Typically, a researcher needs only those records having specified values or ranges of values of the ancillary parameters (e.g., pertaining to a certain type of antenna or to a certain interval of time). An interactive program in the C language called "Parafile" operates in conjunction with the program "Paracomp" to extract the amplitude and phase information of only such records from a file while ignoring the other records. The output of these file-handling programs is a combination of two files: one containing the amplitudes or powers, the other containing the phases.

FORTRAN programs are used to process the file-handling outputs into any of several useful forms. FORTRAN program 1 computes the probability that the power of the signal equals or exceeds a specified level. FORTRAN program 2 computes the probability density of the signal level and fits a Rician density function to the data points via a least-squares fitting algorithm. Program 3 computes the frequency of the duration of fade. Program 4 computes Fourier transforms of the first 1,024 samples of the input file (see figure).

This work was done by A. V. Kantak of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-17232/TN

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Department of Energy

Technology Application

Ames Laboratory

Method of Generating Chemiluminescent Light

Hydrogen sulfide is often emitted into the atmosphere during the industrial production of methanol, methane, glycols and other hydrocarbons. The toxicity of this gas makes it critically important to be able to continuously monitor its presence in the atmosphere. Amounts as small as one part per million can also poison costly catalysts used to produce petrochemicals.

Continuous monitoring by present methods is difficult and requires long collection times, concentration of the hydrogen sulfide and time-consuming chemical preparation. Thus, truly continuous monitoring cannot be achieved.

Ames Laboratory researchers have addressed this problem by developing a way to continuously monitor hydrogen sulfide and methyl mercaptan (another sulfur-containing compound) at levels as low as one part per billion, and with high sensitivity. The method is based on a new reaction that involves chemiluminescent technology for detection. Chemiluminescence refers to the ability of materials to give off a faint glow during reactions with certain chemical compounds.

The Ames researchers have discovered that hydrogen sulfide or methyl mercaptan will react with chlorine dioxide and produce sulfur atoms. These sulfur atoms recombine to form electronically excited S_2, which luminesces. A single photon is emitted for every two sulfide-containing species, thus providing a qualitative and quantitative measurement of the toxic compounds.

The reaction must be conducted at low pressure to prevent the reaction from being quenched. The volume of the reaction zone must be small and and ClO_2 gas must be kept in excess. This method improves upon existing technology in that it is absent of interferring signals from other components in the atmosphere, eliminates errors, and permits truly continuous monitoring.

Literature: S. R. Spurlin and E.S. Yeung, *Anal. Chem.*, 54, 318 (1982).

Patent /License Status: U.S. Patent No. 4,634,574.

Potential Applications/Spinoffs: Air pollution monitoring and health effects monitoring.

For More Information on this Technology: Contact Daniel E. Williams, Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, Iowa 50011 (515)294-2635.

AL 88-06-U (Update of AL 87-01)

Oak Ridge National Laboratories

High-Efficiency Scintillation Detector for Thermal and High-Energy Neutrons

Subcriticality experiments require high-efficiency radiation detectors that are sensitive to gamma radiation and to fast (high-energy) and thermal (low-energy) neutrons. In the past, separate detectors were needed to detect the various types of radiation emitted in these experiments. A new scintillation detector, developed at ORNL, can simultaneously detect gamma radiation and fast and thermal neutrons.

This new detector consists of two scintillators assembled on a single photomultiplier tube (Fig. 1). One scintillator, made of glass loaded with lithium that is enriched with ^{6}Li, has a very high efficiency for low-energy neutrons. It is located adjacent to the radiation entrance window and is optically coupled to the second scintillator. The second scintillator, a 4-in.-thick piece of plastic, has high efficiency for higher-energy neutrons. Both scintillators are sensitive to gamma radiation, the plastic having higher efficiency because it is much thicker. The plastic scintillator is optically coupled to the photomultiplier tube. Scintillations occurring in either scintillator are detected by the photomultiplier tube, which generates an electronic pulse for counting each event.

This detector would be suitable for a variety of health physics monitoring applications. Other potential applications for this detector include nuclear fuel processing, nuclear waste storage, and neutron-gamma measurements in space.

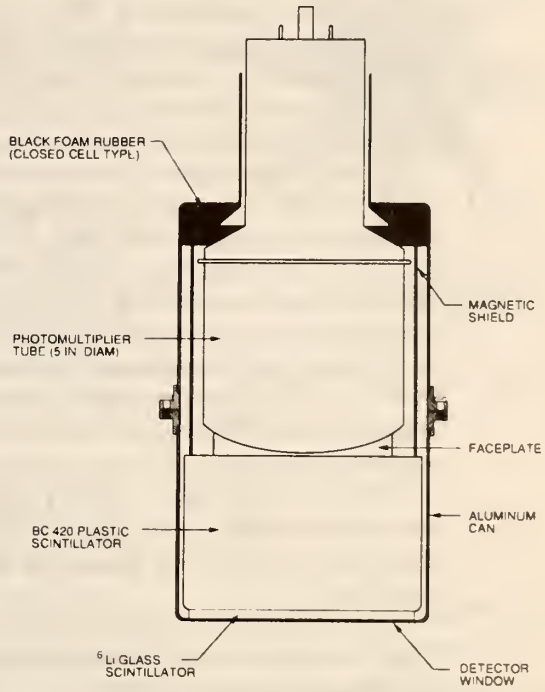


Fig. 1. The high-efficiency scintillation detector for thermal and high-energy neutrons.

Additional information:

Office of Technology Applications
Martin Marietta Energy Systems, Inc.
P.O. Box 2008
Oak Ridge, TN 37831-6257

Telephone: (615) 574-4192; FTS 624-4192

M. M. Chiles, J. T. Mihalczo, and E. D. Blakeman, "High-Efficiency Scintillation Detector for Thermal and High-Energy Neutrons and Gamma Radiation," *IEEE Trans. Nucl. Sci.* **35**(1), 110-11 (February 1988).

Monochromator for Continuous Spectrum X-Ray Radiation

Synchrontron radiation offers many advantages as a source of x-rays for experimental use. The radiation is highly collimated, has high flux, can be polarized up to 100 percent, and extends over a wide range of wavelengths or energies. Various combinations of these features may be required for different types of x-ray experiments. For example, a beam of high flux and low energy resolution may be required for diffuse scattering measurements.

Various monochromators have been designed to meet special synchrontron experimental requirements but no one monochromator has sufficient flexibility to accommodate different experiments having widely disparate requirements.

Ames Laboratory has addressed this problem by developing a monochromator with the flexibility and adaptability needed for a variety of experimental conditions. This monochromator consists of two diffraction means, two rotational motion means, and a translational motion means. The important feature of the invention is that the two diffraction crystals can be independently rotated and one of them can be translationally moved to maintain Bragg's law at all energies. These movements are controlled by computer which allows for precise repositioning in very small increments.

The two diffraction crystals are mounted on crystal holders that are mounted on the rotational motion means. The holders can be removed easily so the crystals can be switched. This allows users to change a monochromator from non-dispersive operation to low dispersive operation.

The invention is a highly flexible system which provides optimum operation for a wide range of needs of x-ray scattering experiments. The present design also lends itself well to modifications and variations.

Literature: J.-L. Staudenmann, et al., "Versatile Monochromator for Synchrontron X-rays," *Nuclear Instr. and Meth.*, Vol 222, 1984, p. 177.

Patent/License Status: U.S. Statutory Invention Registration, Reg. No. H313.

Potential Applications/Spinoffs: Any device requiring beam parallelism.

For More Information on this Technology: Contact Daniel E. Williams, Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, Iowa 50011 (515)294-2635.

AL 88-04

NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Chopping-Wheel Optical Attenuator

A rotating star-shaped wheel provides adjustable attenuation independent of wavelength.

A star-shaped rotating chopping wheel provides adjustable time-averaged attenuation of a narrow beam of light without changing the length of the optical path or the spectral distribution of the light. The duty cycle or attenuation factor of the chopped beam is controlled by adjusting the radius at which the beam intersects the wheel (see figure). The attenuation factor is independent of wavelength.

The attenuation factors of variable neutral-density filters vary with wavelength. Such filters also affect the lengths of optical paths and can cause undesirable reflection, refraction, and scattering.

The chopping-wheel attenuator is useful in systems in which the chopping frequency is well above the frequency-response limits of the photodetectors that receive the chopped light. These include dc and low-pass-filtered detectors and such integrating detectors as photographic film and charge-coupled devices. The chopped beam produced by the attenuator can also be used in systems that use synchronous detection with lock-in amplifiers.

For a chopping wheel with uniformly-spaced symmetrical triangular blades, like the one shown in the figure, the radial position, r, of the beam as a function of transmission factor T is given by

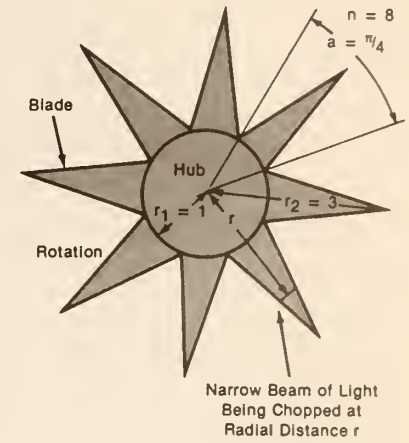
$$r(T) = r_2/\{[r_2/r_1 \sin(a/2) - 1/\tan(a/2)] \sin[a(1-T)/2] + \cos[a(1-T)/2]\}$$

where r_1 is the radius of the hub, r_2 is the radius at the tip of the blades, a is $2\pi/n$, and n is the number of blades. The inverse function, $T(r)$, has also been derived. A computer program in the BASIC language tabulates and graphs $r(T)$ for wheels with values of r_1, r_2, and n selected by the user.

The shape of the curve is affected strongly by the hub and tip radii and to a lesser extent by the number of blades. In practice, one designs a wheel by selecting the radii to obtain the general behavior desired and then choosing the number of blades for ease of fabrication and for chopping frequency. While it would be possible to calculate a blade shape that would provide a linear relation between radius and transmission, the edges of the blades would be curved and thus more difficult to fabricate.

A chopping-wheel attenuator has been used in an experiment to measure the angular dependence of light scattered from diffraction gratings. Scattering from a neutral-density filter would have altered the measured angular dependence. The 12-blade wheel used in this experiment was cut from sheet metal and painted flat black. Its attenuation properties agreed with the equation.

This work was done by Douglas B. Leviton of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-13139/TN



A **Chopping-Wheel Attenuator** provides variable time-averaged attenuation of a narrow beam of light by controlling the duty cycle of the chopped beam. The graph shows normalized radial position of the beam vs. time-averaged transmission (duty cycle) for the eight-pointed wheel.

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Transportation & Components

0424 Airplane Takeoff-and-Landing Performance Monitoring System—An algorithm and display system are designed to increase the safety of flight. (Licensing Opportunity)

0425 General-Aviation Control Loader—An artificial-feel system is designed for general-aviation flight simulators.

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Airplane Takeoff-and-Landing Performance Monitoring System

An algorithm and display system are designed to increase the safety of flight.

The Airplane Takeoff-and-Landing Performance Monitoring System (TOPMS) is designed to increase safety during takeoffs and landings of aircraft. Pilots currently rely heavily on flight manuals for planning takeoffs and on judgment during takeoff or abort. The TOPMS provides pilots with graphic information crucial to their decision to continue or reject a takeoff. If a takeoff is rejected or a landing is in progress, the TOPMS also provides crucial information relative to where the airplane can be brought to a stop.

The TOPMS provides information not currently available in the cockpit and presents it in forms that are simple and easily monitored by the pilots. The information is generated in a two-part algorithm and could be displayed to the pilots by electronic screens on their instrument panels or projected as a head-up display. The algorithm calculates a pretakeoff prediction of nominal acceleration and determines where the airplane will reach takeoff speed, based on such factors as the gross weight of the airplane, the slope and the condition of the surface of the runway, the ambient temperature, the atmospheric pressure, the wind conditions, and the flap setting.

The pretakeoff part of the algorithm also determines the remaining-groundroll-plus-air distance needed for the airplane to clear a 35-ft (11-m) obstacle at the departure end of the runway after an engine failure at the decision speed and also the distance required to brake to a stop after the same engine failure. The initial groundroll distance to the point where engine failure occurs plus the greater of the two distances above constitute an important metric called the balanced field length, or the minimum runway length required for the particular airplane and the existing conditions. This value is displayed on the TOPMS for reference before the pilot enters the actual length of the runway about to be used.

After the takeoff is underway, a real-time part of the algorithm continuously updates the prediction of the distance required to reach takeoff speed, based on sensed acceleration. In addition, the real-time part continuously calculates the distance required to stop the airplane, based on specified delays for the initiation of abort and deceleration resulting from maximum wheel braking and deployment of the speed brakes. The algorithm also calculates a stopping point based on the actual deceleration of the airplane. The pilot can see on the display where the airplane will be brought to a stop if a reduced level of braking is used or if reverse thrust is added. These same calculations can be applied to a landing situation.

The TOPMS display and logic were modified into a refined form following a real-time simulator evaluation by over 40 experienced NASA, Federal Aviation Administration, Air Force, airline, and industry pilots. It summarizes critical/priority information into a "go/no-go" situation-advisory flag. Additionally, it indicates the points on the runway where such important events as the decision speed, rotation speed, and expected stopping point will occur. Off-nominal acceleration performance and engine failures are also detected and flagged.

This work was done by David B. Middleton and Lee H. Person, Jr., of **Langley Research Center** *and Raghavachari Srivatsan of the University of Kansas. Further information may be found in NASA TM-89001 [N86-31591/NSP] and NASA CR-178255 [N87-20264/NSP], both titled "Development of a Takeoff Performance Monitoring System," and AIAA Paper 87-2256, "Evaluation of a Takeoff Performance Monitoring System."*

Copies of N86-31591 and N87-20264 may be purchased [price code: A02] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Copies of AIAA Paper 87-2256 may be purchased [prepayment required] from AIAA Technical Information Service Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center
Refer to LAR-13734/TN

Langley Research Ctr.
Hampton, VA 23665
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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

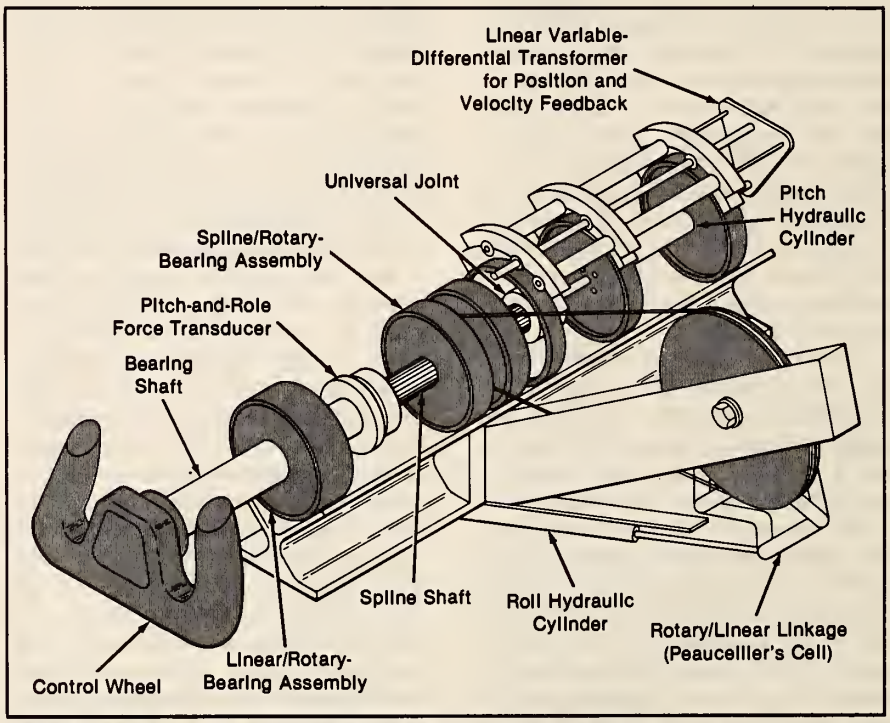
General-Aviation Control Loader

An artificial-feel system is designed for general-aviation flight simulators.

A variable-characteristic artificial-feel system, or control-loading system, is compatible with the requirements of real-time flight-simulation research for the general-aviation-class airframe. Control-loading systems have long been used to provide realistic control-force feedback in the simulation of flight for both training and research. However, these systems have been directed at fighter and transport applications. The new system was developed to replace directly the lateral and longitudinal (wheel and column) controls in a general-aviation cockpit for use in flight-simulation research.

The system (see figure) employs two small-bore hydraulic cylinders controlled by precise electromechanical servo-flow-control valves. It uses a Peaucellier's cell to convert the linear motion of the roll hydraulic cylinder to rotary motion. An analog operational-amplifier network serves as an interface with a digital computer via analog-to-digital signal-conversion equipment.

The system provides computer-controlled force feel as the control wheel is moved by the pilot in the longitudinal (pitch) and lateral (roll) axes. Potentiometers are used to set required values of such quantities as gradients, damping, and cable stretching. Analog multipliers enable the computer to vary gradients and damping proportionally from 0 to 100 percent of maximum simulated values.



Using a Peaucellier's Cell To Convert Linear Motion to Rotary Motion, this control-loading system provides realistic control-force feedback to the cockpit wheel and column controls.

The development of the system is complete, and the unit is operational. The system is installed in NASA Langley Research Center's General-Aviation Cockpit Simulator, where it serves as the primary flight-control system.

This work was done by Daniel W. Baltrus, Leroy F. Albang, John A. Hallinger, and W. Wayne Burge of Sperry Corp. for **Langley Research Center.**

LAR-13707/TN

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Permit No. G-292

- Agriculture & Food
- Computers
- Electrotechnology
- Energy
- Engineering
- Environmental Science & Technology
- Manufacturing, Machinery, & Tools
- Materials
- Medicine & Biology
- Natural Resources Technology & Engineering
- Physical Sciences
- Transportation & Components

Route To: